Space engineering

Electromagnetic compatibility

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Introduction

Electromagnetic compatibility of a space system or equipment is the ability to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

The space system is designed to be compatible with its external natural, induced, or man-made electromagnetic environment. Natural components are lightning for launchers, the terrestrial magnetic field for space vehicles. Spacecraft charging is defined as voltage building-up of a space vehicle or spacecraft units when immerged in plasma. Electrostatic discharges result from spacecraft charging with possible detrimental effects. External man-made interference, intentional or not, are caused by radar or telecommunication beams during ground operations and the launching sequence. Intersystem EMC also applies between the launcher and its payload or between space vehicles.

Intrasystem EMC is defined between all electrical, electronic, electromagnetic, and electromechanical equipment within the space vehicle and by the presence of its self-induced electromagnetic environment. It comprises the intentional radiated electromagnetic fields and parasitic emission from on-board equipment. Both conducted and radiated emissions are concerned. An electromagnetic interference safety margin is defined at system critical points by comparison of noise level and susceptibility at these points.

1
Scope

EMC policy and general system requirements are specified in ECSS-E-20B.

This ECSS-E-20-07 Standard addresses detailed system requirements (Clause 4), general test conditions, verification requirements at system level, and test methods at subsystem and equipment level (Clause 5) as well as informative limits (Annex A).

Associated to ECSS-E-20-07 is ECSS-E-20-06, which addresses charging control and risks arising from environmental and vehicle-induced spacecraft charging when ECSS-E-20-07 addresses electromagnetic effects of electrostatic discharges.

Annexes A to C of ECSS-E-20B document EMC activities related to ECSS-E-20-07: the EMC Control Plan (Annex A) defines the approach, methods, procedures, resources, and organization, the Electromagnetic Effects Verification Plan (Annex B) defines and specifies the verification processes, analyses and tests, and the Electromagnetic Effects Verification Report (Annex C) document verification results. The EMEVP and the EMEVR are the vehicles for tailoring this standard.

2
Normative references

The following dated normative documents are called by the requirements of this ECSS Standard and therefore constitute requirements to it. Subsequent amendments to, or revisions of any of these publications do not apply.

NOTE However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below.

ECSS-P-001B	ECSS - Glossary of terms
ECSS-E-20B	Space engineering - Electrical and electronic
ECSS-E-20-06A	Space engineering - Spacecraft charging
ECSS-E-33-11A	Space engineering - Explosive systems and devices
ECSS-E-50-14A	Space engineering - Discrete interfaces
IEC 61000-4-2-(Edition 1.2)	Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test

3
Terms and definitions

3.1 Terms defined in other standards

For the purpose of this Standard, the terms and definitions from ECSS-P-001B apply, in particular for the following terms:

critical item

customer

equipment

item

launcher, launch vehicle

mission

requirement

safety critical function

supplier

spacecraft, space vehicle

subsystem

system

test

verification

For the purposes of this document, the following terms have a specific definition contained in ECSS-E-20B.

conducted emission

electromagnetic compatibility

electromagnetic compatibility control

electromagnetic interference

electromagnetic interference safety margin

emission

high-voltage

lightning indirect effects

radiated emission

radiofrequency

susceptibility

susceptibility threshold

For the purposes of this document, the following terms have a specific definition contained in ECSS-E-20-06A.

electrostatic discharge (ESD)

secondary arc

For the purposes of this document, the following term has a specific definition contained in ECSS-E-33-11A:

electro-explosive device (EED)

3.2 Terms specific to the present standard

3.2.1 ambient level

level of radiated and conducted signal, and noise that exist at the specified test location and time when the equipment under test is not operating

NOTE Examples are atmospherics, interference from other sources, and circuit noise or other interference generated within the measuring set compose the “ambient level”.

3.2.2 antenna factor

factor that, when properly applied to the voltage at the input terminals of the measuring instrument, yields the electric or magnetic field strength

NOTE 1 This factor includes the effects of antenna effective length, mismatch, and transmission losses.

NOTE 2 The electric field strength is normally expressed in V/m and the magnetic field strength in A/m or T.

3.2.3 common mode voltage

voltage difference between source and receiver ground references

3.2.4 contact discharge method

method of testing in which the electrode of the high-voltage test generator is held in contact with the discharge circuit, and the discharge actuated by a discharge switch

3.2.5 electromagnetic environmental effects

impact of the electromagnetic environment upon equipment, systems, and platforms

NOTE It encompasses all electromagnetic disciplines, including electromagnetic compatibility; electromagnetic interference, electromagnetic vulnerability, hazards of

electromagnetic radiation to personnel, electro-explosive devices, volatile materials, and natural phenomena effects.

3.2.6 field strength

resultant of the radiation, induction and quasi-static components of the electric or magnetic field

NOTE The term "electric field strength" or "magnetic field strength" is used, according to whether the resultant, electric or magnetic field, respectively, is measured.

3.2.7 ground plane

metal sheet or plate used as a common reference point for circuit returns and electrical or signal potentials

3.2.8 improper response

subsystem or equipment response which can be either inadvertent or unacceptable

3.2.9 inadvertent response

proper subsystem functional response (within normal range of limits) actuated by electromagnetic interference, but occurring at other than the normal operational cycle, which in turn causes improper response to the total space system

3.2.10 line impedance stabilization network (LISN)

network inserted in the supply leads of an apparatus to be tested which provides, in a given frequency range, a specified source impedance for the measurement of disturbance currents and voltages and which can isolate the apparatus from the supply mains in that frequency range

3.2.11 not operating

condition wherein no power is applied to the equipment

3.2.12 overshield

shield surrounding a bundle or a shielded cable

3.2.13 passive intermodulation product

generation of a signal at frequency $f = n*f_1 + m*f_2$ from two signals at frequencies f_1 and f_2, where n and m are positive or negative integers, by a passive device, usually an electrical contact

3.2.14 port

place of access to a device or network where energy can be supplied or withdrawn, or where the device or network variables can be observed or measured.

3.2.15 power quality requirements

requirements which define the conducted voltage noise or impedance the power user can expect

NOTE Noise e.g. from load regulation, spikes, and sags.

3.2.16 soft magnetic material

ferromagnetic material with a coercivity smaller than 100 A/m

3.2.17 spurious emission

electromagnetic emission from the intended output terminal of an electronic device, but outside of the designed emission bandwidth

3.2.18 test antenna

antenna of specified characteristics designated for use under specified conditions in conducting tests

3.2.19 unit

equipment that is viewed as an entity for purposes of analysis, manufacturing, maintenance, or record keeping

NOTE Hydraulic actuators, valves, batteries, and individual electronic boxes such as on-board computer, inertial measurement unit, reaction wheel, star tracker, power conditioning unit, transmitters, receivers, or multiplexers.

3.3 Abbreviated terms

The following abbreviated terms are defined and used within this Standard:

Abbreviation	Meaning
AC	alternating current
ACS	attitude control system
AM	amplitude modulation
AWG	American wire gauge
BCI	bulk cable injection
CE	conducted emission
CS	conducted susceptibility
CW	continuous wave
DC	direct current
EED	electro-explosive device
EGSE	electrical ground support equipment
EHF	extremely high frequency (30 GHz-300 GHz)
EM	electromagnetic
EMC	electromagnetic compatibility
EMCAB	electromagnetic compatibility advisory board
EMCCP	electromagnetic compatibility control plan
EMEVP	electromagnetic effects verification plan
EMEVR	electromagnetic effects verification report
EMI	electromagnetic interference
EMISM	electromagnetic interference safety margin

ESD	electrostatic discharge
EUT	equipment under test
HV	high voltage
ICD	interface control document
LEO	low-altitude earth orbiting
LF	low frequency
LISN	line impedance stabilization network
MGSE	mechanical ground support equipment
PAM	pulse amplitude modulation
PCM	pulse coded modulation
RE	radiated emission
RF	radio frequency
RMS	root mean square
RS	radiated susceptibility
SHF	super-high frequency (3 GHz-30 GHz)

4
Requirements

4.1 General system requirements

EMC policy and general system requirements, and the spacecraft charging protection program are specified in Clause 6 and Annex A of ECSS-E-20A.

4.2 Detailed system requirements

4.2.1 Overview

This clause 4.2 define the requirements for design and realization at system level. They are the basis for definition of activities of the EMC programme to ensure space-system-level compatibility with minimum impact to programme, cost, schedule, and operational capabilities.

4.2.2 EMC with the launch system

4.2.2.1 General

General system requirements for EMC with the launch system are defined in ECSS-E20B, clause 6.3.2.2.

4.2.2.2 Detailed system requirements

a. Overload capability of the spacecraft RF receivers during the pre-launch and launch phases with or without fairing, shall be demonstrated by the spacecraft supplier.

NOTE 1 It is expected the electromagnetic environment generated by companion payloads is assessed by the launching company and addressed in the User's Manual.

NOTE 2 A conductive fairing is likely to cause resonances and cavity effects.

b. Spacecraft equipment shall not exhibit any malfunction, degradation of performance or deviation beyond the tolerance indicated in its individual specification after being

exposed, even not operating, to the electromagnetic environment from the launcher and launch site.

NOTE Most of spacecraft equipment is not operating during launch. During the launching sequence spacecraft transmitters and receivers (platform and payload) can be either in OFF- or ON-state depending on the launch vehicle.

c. The electromagnetic interference safety margin (EMISM) of safety critical equipment shall be applied to equipment in ON-state during prelaunch and launch phase and to EED's.

4.2.3 Lightning environment

4.2.3.1 General

Protection of the space system against both direct and indirect effects of lightning can be a combination of operational avoidance of the lightning environment and electrical overstress design techniques.

4.2.3.2 Requirements to the space system

a. Assessment of risk, on the launch pad inside the protected area, for the space system and its equipment against direct and indirect effects of lightning before lift-off, shall be performed.

b. The spacecraft supplier shall obtain from the launching company the EM environment imposed on the launcher payloads in case of lightning.

4.2.4 Spacecraft charging and effects

4.2.4.1 General

Mitigation of risks related to spacecraft charging results of a combination of rules and methods preventing voltage build-up and so minimizing the occurrence of ESD, and techniques for controlling EMI from residual ESD.

ECSS-E20B addresses management of spacecraft charging protection and system-level performance under effects of spacecraft charging and related ESD or secondary arcs.

ECSS-E20-06A addresses charging control and risks arising from spacecraft charging and other environmental effects on the spacecraft's electrical behaviour.

4.2.4.2 EMI control requirements to system and equipment in relation with ESD

a. Analysis or tests at system level shall be performed for assessing the threat at subsystem or equipment level.

NOTE Analysis or tests can be defined in the time or frequency domain. They are expected to evaluate the coupling level from the ESD source to critical points.

b. EMI control from residual ESD shall be performed by a combination of shielding and passive or active filtering techniques, implemented on the main structure, at subsystem level or inside equipment.

c. EMI control efficiency shall be verified by test at subsystem or equipment level.

4.2.5 Spacecraft DC magnetic emission

4.2.5.1 Spacecraft with susceptible payload

As part of the EMCCP, a magnetic cleanliness control plan shall document:

a. magnetic control guidelines

b. emission limits to magnetic sources

c. a magnetic budget

d. specific test methods applied to equipments for emission measurement and characterization

NOTE The test method described in 5.5.5 providing a dipole model can be inadequate and replaced by a multiple dipole model or a spherical harmonics model.

4.2.5.2 Attitude control system (ACS)

a. As part of the EMCCP, a magnetic budget shall be maintained providing:

1. Three-axes components of the space vehicle magnetic dipole (component decreasing with the inverse cube law with distance).

NOTE Typical values lie in the range 1 Am^2 or less for small spacecraft to much more than 10 Am^2 for large spacecraft.

2. If the solar array is rotating in the space vehicle axes, separate evaluation for the main body and the solar array (.

3. When the space vehicle is using a magnetic sensor as part of the ACS, evaluation of the magnetic induction at its location.

NOTE The angular deviation is the basic requirement; however, the requirement is generally expressed in terms of modification of the natural field strength at the sensor location. For LEO spacecraft if the error on each axis is less than 1 μT, the modification of the direction is kept less than 20 milliradians.

b. The specified maximum magnetic field value shall comprise the remanent magnetization (magnets, electro-magnets in off-state, or residual perm-up due to hysteresis of soft materials), the induced magnetization of soft materials by the geomagnetic field, and the momentum of current loops.

4.2.6 Radiofrequency compatibility

a. Spurious emissions requirements at antenna ports shall be specified for RF compatibility purpose by the spacecraft supplier.

b. When specifying limits and frequency ranges, the following issues shall be included:

1. sensitivity of possible victim receiver subsystems including out-of-band response

2. no limits apply to transmit frequencies and information carrying modulation bandwidths

3. highest and lowest intentional frequency used by space system receivers

4. antenna port attachments, gain/loss characteristics

4.2.7 Hazards of electromagnetic radiation

Assessment of hazards to electromagnetic radiation is a part of the process required in ECSS-Q-40-02, clause 6.1.

4.2.8 Intrasystem EMC

Intrasystem EMC shall be achieved by:

a. allocation of equipment-level EMI requirements documented in the EMCCP, including:

   1. limits on conducted and radiated emission
   2. susceptibility thresholds

      NOTE Recommended data is defined in Annex A for equipment and subsystems

b. control of conducted and radiated propagation paths methods defined by clauses 4.2.10 to 4.2.13

4.2.9 EMC with ground equipment

a. The EGSE and MGSE used for spacecraft integration and ground testing shall

   1. not degrade the EMC performance of the spacecraft.
   2. have no impact on grounding or isolation.

b. The EGSE shall be immune to signals used for spacecraft susceptibility tests.

4.2.10 Grounding

4.2.10.1 General

As specified in ECSS-E20B, a controlled ground reference concept is defined for the space system. Structural elements, antenna and RF reference grounds, power and signal returns, shields and cable shields, safety grounds, EGSE grounds are considered.

4.2.10.2 Requirements

a. A system-level grounding diagram shall be established including the EGSE.

b. A ground reference shall be identified for each power, signal, or RF source or receiver.

c. An upper value of common mode voltage shall be specified considering:

   1. power quality requirements defined in ECSS-E-20B, clause 5.7.2,
   2. type of detectors and sensitivity,
   3. characteristics of analogue signal monitor receiver circuit, in accordance with ECSS-E-50-14A, clause 5.2.2.2.d,
   4. characteristics of bilevel signal monitor receiver circuit, in accordance with ECSS-E-50-14A, clause 6.1.2.2.2.d,

5. hazards due to fault currents internal to the space vehicle or between the space vehicle and its EGSE.

d. When power and signal share common paths (wire or structure), the magnitude of ground impedance shall be limited over the affected signal spectrum.

NOTE Non-exclusive techniques for reducing the impedance are decrease of common path length, decrease of wire and ground impedance, filters on common paths

4.2.11 Electrical bonding requirements

4.2.11.1 General

Bonding requirements are a mean for fulfilling grounding requirements.

NOTE Bonding for charging control is specified in ECSS-E20-06.

4.2.11.2 Normative provisions

a. A vehicle bonding attachment point connected to the vehicle structure shall be provided as a ground reference point at system level.

b. An equipment bonding stud connected to the unit housing shall be provided as a ground reference at equipment level.

c. Each unit housing shall be bonded to the nearby spacecraft structure from the equipment bonding stud.

d. The DC resistance between the equipment bonding stud and the nearby spacecraft structure shall be less than 2,5 mΩ.

e. The inductance between the equipment bonding stud and the nearby spacecraft structure shall be less than 30 nH.

NOTE Example of formula for bonding strap inductance calculation commonly used:
$L = 200\ a\ [\mathrm{Log}_e(2a/b) + 0.5 + 0{,}22\ b/a]$
L inductance in units of nH
a: strap length in units of m
b: width plus thickness of the strap in units of m

f. The DC resistance between the unit housing and the vehicle bonding attachment point shall be less than 20 mΩ.

g. The DC resistance between the unit housing and the vehicle bonding attachment point may be split as shown in 0.

h. Bonds shall be capable to carry the fault currents determined by analysis at system level, without fusing, burning, or arcing.

i. If the structure is used as the return current path, bonding provisions shall be such that DC and AC voltage drops along power paths comply with clause 4.2.10.2.4.2.10.2c.

4.2.11.3 External grounds

The functionality of connecting grounding cables for charge equalization shall be provided on space systems.

NOTE Charge equalization is needed prior to implementing other procedures or the application of power across the interface

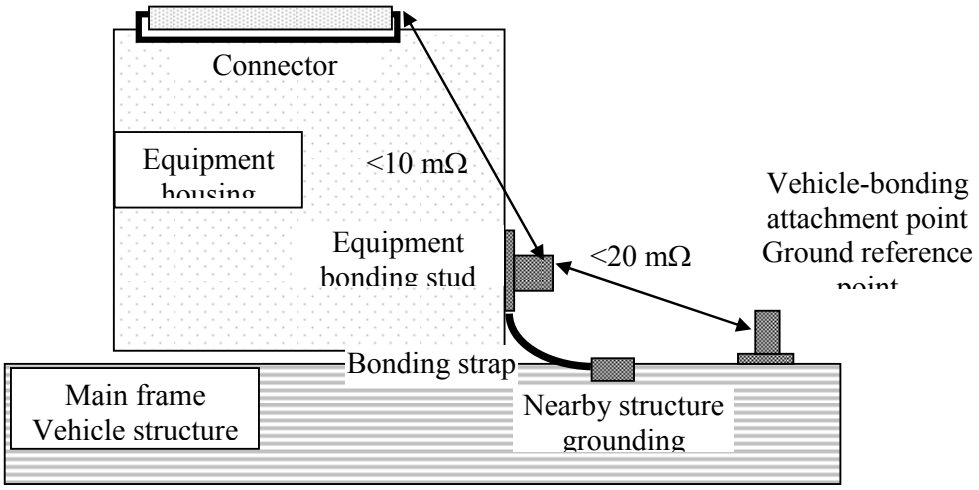

Figure 4-1: Bonding requirements

4.2.12 Shielding (excepted wires and cables)

4.2.12.1 General

When shielding is used to control EMC with the environment, it can be provided by the basic space vehicle structure designed as a "Faraday cage", by enclosures of electronics boxes, or by cable or bundle overshields.

4.2.12.2 Requirement

Electronics units and cables external to the basic space vehicle structure shall have individual shields providing attenuation to EMI.

NOTE It is important to consider apertures used for pressure drop during ascent and for outgassing.

4.2.13 Wiring (including wires and cables shielding)

4.2.13.1 Classification of cables

a. Categorisation of harness and separate routings for wires of different categories shall be defined as follows:

   1. applicable to critical lines as defined in ECSS-E-20B, clause 6.3.1.

   2. made on the basis of the characteristics of the signals on the wire (and hence the interference generated), and on the susceptibility of the circuit to EMI.

b. Wires falling into one category shall be assembled into a same bundle.

c. Bundles of different categories shall be separated either by a separation distance of 5 cm from the outer circumference or by a metallic screen when they are routed on parallel paths.

   NOTE Overshields or spacecraft walls can be used to fulfil the requirement.

d. Wires and cables shall be marked in such a manner that personnel can visually identify the EMC category for each wire or cable.

4.2.13.2 Cable shields

a. Cable shields shall not be used as an intentional current carrying conductor, except coaxial cables in radiofrequency circuits and high-speed data links using coaxial cables.

b. Cable shields, other than overshields, shall have an insulated sheath to prevent uncontrolled grounding

c. Connectors used to carry shielded wires shall:

1. not use a nonconductive finish,

2. provide contact to the equipment housing with a resistance less than 10 mΩ through the equipment connector body as shown Figure 4-1.

d. Bonding of cable shields shall be as following:

1. bonding to chassis ground is performed at both ends:

(a) through the equipment connector body,

(b) using a backshell that provides for circumferential bonding of shields, or using a halo-ring.

NOTE No grounding inside the equipment through a connector ground pin in order to prevent any perturbation inside the equipment.

2. Connection to electrical reference is performed through dedicated pins

NOTE This case typically appears in the design of detection chains

e. Overshields shall be bonded to chassis ground:

1. at both ends,

2. using a 360° direct contact or a bond strap of less than 30 nH

NOTE see NOTE of clause 4.2.11.2.4.2.11.2e

f. Overshields should be bonded to chassis ground at intermediary points with a separation distance less than 1m between two grounding points

5
Verification

5.1 Overview

This Clause specifies general conditions for EMC testing, requirements for verification at system level and detailed procedures for unit and subsystem level testing.

5.2 General

5.2.1 Electromagnetic effects verification plan

The electromagnetic effects verification plan (EMEVP) provides the instruction for conducting all activities needed to verify electromagnetic effects requirements. This document defines the approach, methods, procedures, and specific test conditions. The content is specified in Annex B of ECSS-E-20B. The EMEVP is the vehicle for tailoring procedures and test conditions.

5.2.2 Electromagnetic effects verification report

The electromagnetic effects verification report (EMEVR) documents activities and report analysis or test results in relation with the verification of the electromagnetic effects. It is established based on the electromagnetic effects verification plan (EMEVP). The content of the EMEVR is defined in Annex C of ECSS-E-20B supplemented by specific requirements defined hereafter in 5.4 and 5.5.

5.3 Test conditions

5.3.1 Measurement tolerances

The tolerance shall be as follows:

a. Distance: ±10%

b. Frequency: ±2%

c. Amplitude, measurement receiver: ±2 dB

d. Amplitude, measurement system (includes measurement receivers, transducers, cables, connectors): ±3 dB

e. Time (waveforms): ±10%

f. Resistors: ±5%

g. Capacitors: ±20%

5.3.2 Test site

5.3.2.1 Overview

Shielded enclosures or unshielded sites are used for testing.

Shielded enclosures prevent external environment signals from contaminating emission measurements and susceptibility test signals from interfering with electrical and electronic items near the test facility.

In unshielded sites, the tests are performed during times and conditions when the electromagnetic ambient is at its lowest level.

5.3.2.2 Shielded enclosures

a. The enclosures shall be large such that the EUT arrangement requirements of 5.3.6 and antenna positioning requirements described in the individual test procedures are satisfied.

b. RF absorber material (e.g. carbon impregnated foam pyramids, and ferrite tiles) shall be used when performing electric field radiated emissions or radiated susceptibility testing to reduce reflections of electromagnetic energy and to improve accuracy and repeatability.

c. The RF absorber shall be placed above, behind, and on both sides of the EUT, and behind the radiating or receiving antenna as shown in 0.

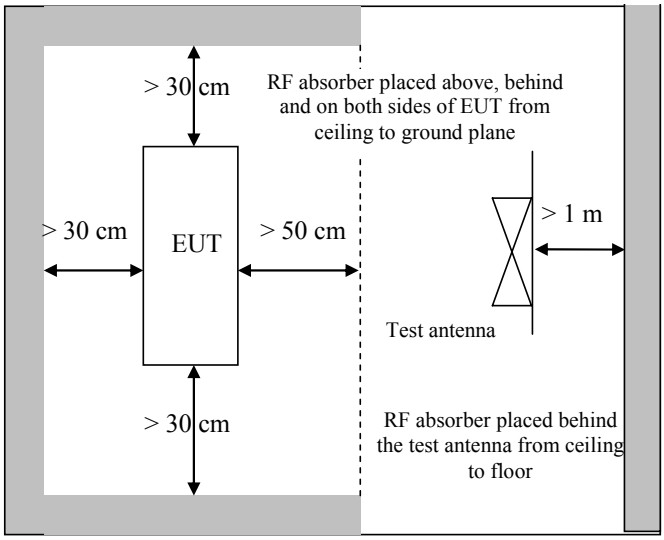
> 30 cm
RF absorber placed above, behind and on both sides of EUT from ceiling to ground plane
> 30 cm
EUT
> 50 cm
> 1 m
Test antenna
> 30 cm
RF absorber placed behind the test antenna from ceiling to floor

Figure 5-1: RF absorber loading diagram

d. Minimum performance of the material shall be as specified in Table 5-1.

NOTE The manufacturer's specification of their RF absorber material (basic material only, not installed) can be used.

Table 5-1: Absorption at normal incidence

Frequency	Minimum absorption
80 MHz – 250 MHz	6 dB
above 250 MHz	10 dB

5.3.2.3 Ambient electromagnetic level

a. The ambient electromagnetic level shall be measured with the EUT not operating and all auxiliary equipment turned on.

b. During testing, at least one of the following conditions shall be met:

- the ambient is at least 6 dB below the individual test limits,
- the EUT complies with the individual test limits,
- it is shown that recorded data exceeding the limits cannot be generated by the EUT (emission tests) or cannot sensitize the EUT (susceptibility tests).

c. Background plots shall be reported for each test configuration unless all recorded data is at least 6dB below the individual test limits.

5.3.2.4 Ambient conducted level

Ambient conducted levels on power leads shall be measured with the leads disconnected from the EUT and connected to a resistive load that draws the same rated current as the EUT.

5.3.3 Ground plane

5.3.3.1 General

a. If the actual installation is known, the EUT shall be installed on a ground plane that simulates the actual installation.

b. If the actual installation is unknown or multiple installations are expected, then the EUT shall be installed on a metallic ground plane.

c. Ground planes shall be 2 m² or larger in area with the smaller side no less than 75 cm.

d. When a ground plane is not present in the actual EUT installation, the EUT shall be placed on a non-conductive table.

NOTE In such a case, test methods are specific and are likely to differ from the ones in the present standard

5.3.3.2 Metallic ground plane

a. When the EUT is installed on a metallic ground plane, the ground plane shall have a DC surface resistance not larger than 0,1 mΩ per square.

b. The DC resistance between metallic ground planes and the shielded enclosure shall be 2,5 mΩ or less.

c. The metallic ground planes shall be electrically bonded to the floor or wall of the basic shielded room structure at least once every 1 m.

d. The metallic bond straps shall be solid and maintain a five-to-one ratio or less in length to width.

e. Metallic ground planes used outside a shielded enclosure shall extend at least 1,5 m beyond the test setup boundary in each direction.

5.3.3.3 Composite ground plane

a. When the EUT is installed on a conductive composite ground plane, the surface resistivity of the actual installation shall be used.

b. Composite ground planes shall be electrically bonded to the enclosure with means suitable to the material.

5.3.4 Power source impedance

a. The impedance of power sources providing input power to the EUT shall be controlled by Line Impedance Stabilization Networks (LISN's) for all measurement.

b. LISN's shall not be used on output power leads.

c. The LISN's shall be located at the power source end of the exposed length of power leads specified in 5.3.6.6.

d. The LISN circuit shown in Figure 5-2 shall be used.

NOTE 1 The LISN can be split in several cases, one per power lead.

NOTE 2 The series inductances represent the inductances of the wiring; the series resistances represent the resistances of the wiring and of the central protections

NOTE 3 The 50 Ω resistors result in 100 Ω at high frequency, similar to the characteristic impedance of the line

NOTE 4 The feed-through capacitors provide a short-circuit at high frequency and make the LISN symmetrical

NOTE 5 Connecting the regulation wires of the laboratory supply at the LISN input in order to provide sufficiently low impedance at low frequency is an appropriate method. The source impedance is then dominated by the series resistances in the LISN. Alternatively, a large capacitor (between 1 mF and 10 mF) will be used.

e. If no value is specified x = 2 μH and y = 0,1 ohm shall be used.

NOTE The x and y values, respectively the inductance and the resistance inserted in each lead are expected in the EMEVP.

f. Magnetic coupling between inductors shall be avoided.

g. If the return line is grounded at the power source in the actual installation (star distribution), the return line of the LISN shall be grounded on the power source side.

h. If the return line(s) of the actual installation is locally grounded (chassis return), the return line of the LISN need not be provided, and the tests shall be performed with the return(s) tied to case.

i. The LISN impedance shall be measured at least annually under the following conditions:

1. the impedance, measured between the power output lead on the EUT side of the LISN and the metal enclosure of the LISN,
2. an unterminated power input terminal on the power source side of the LISN.

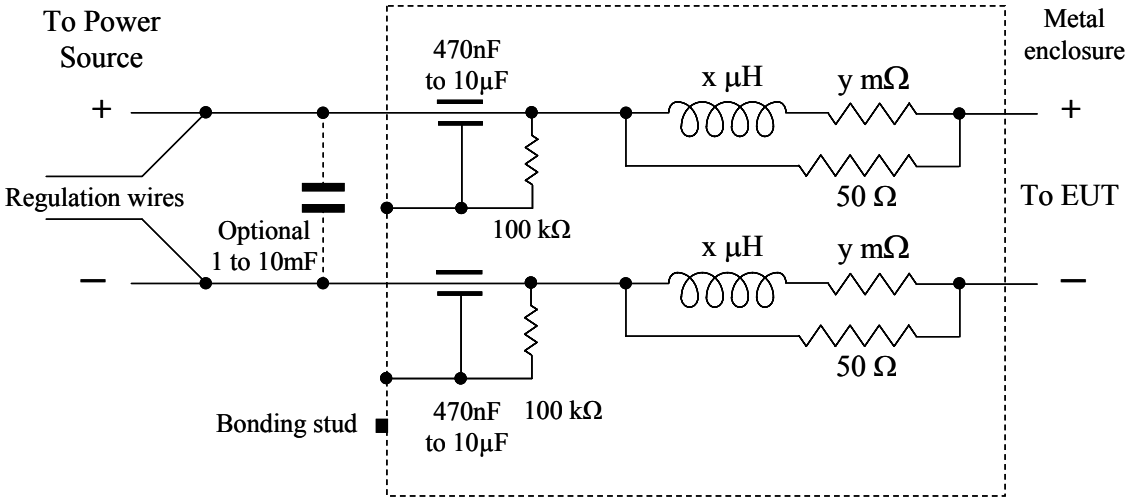

Figure 5-2: Line impedance stabilization network schematic

5.3.5 General test precautions

5.3.5.1 Safety

Clause 4.2.7 shall apply for tests involving high electromagnetic power or high voltage test equipment.

5.3.5.2 Excess personnel and equipment

Only the equipment and the personnel used to perform the test shall be present in the test area or enclosure.

5.3.5.3 Overload precautions

a. Checks shall be performed to assure that an overload condition does not exist.

NOTE Measurement receivers and transducers are subject to overload, especially receivers without preselectors and active transducers.

b. Overload condition shall be corrected.

NOTE This can be done by instrumentation changes.

5.3.6 EUT test configurations

5.3.6.1 General

The EUT shall be configured as shown in the general test setup of Figure 5-3 and maintained during all testing.

NOTE For radiated tests, it may be desirable to have the LISN outside of the shielded room.

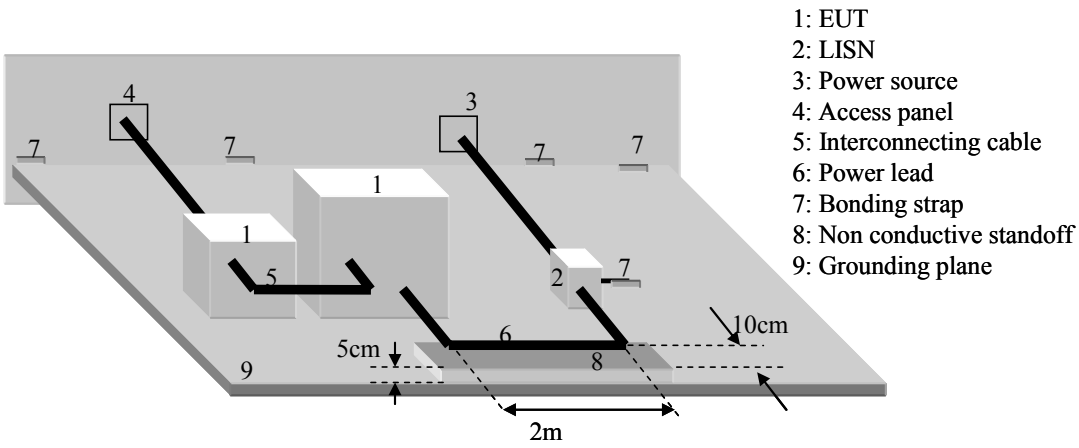

Figure 5-3: General test setup

5.3.6.2 Bonding of EUT

Only the provisions included in the design of the EUT shall be used to bond units.

5.3.6.3 Shock and vibration isolators

a. EUT's shall be secured to mounting bases having shock or vibration isolators if such mounting bases are used in the actual installation

b. The bonding straps furnished with the mounting base shall be connected to the ground plane.

c. When mounting bases do not have bonding straps, bonding straps shall not be used in the test setup.

5.3.6.4 Safety grounds

When external terminals, connector pins, or equipment grounding conductors are available for safety ground connections and are used in the actual installation, they shall be connected to the ground plane.

NOTE Arrangement and length are specified in 5.3.6.6.

5.3.6.5 Orientation of EUT's

a. EUT's shall be oriented such that surfaces that produce maximum radiated emissions and respond most readily to radiated signals face the measurement antennas.

b. Bench mounted EUTs comprising interconnecting cables shall be located (10 ± 2) cm from the front edge of the ground plane.

5.3.6.6 Construction and arrangement of EUT cables

5.3.6.6.1 General

a. Electrical cable assemblies shall simulate actual installation and usage.

NOTE 1 Proper construction techniques such as use of twisted pairs, shielding, and shield terminations are determinant features.

NOTE 2 Details on the cable construction used for testing are defined in the EMEVP (ECSS-E20B, annex B) and maintained in the EMEVR (ECSS-E20B, annex C).

b. Shielded cables or shielded leads (including power leads and wire grounds) within cables shall be used only if they have been specified in installation requirements.

5.3.6.6.2 Interconnecting leads and cables

a. Individual leads shall be grouped into cables in the same manner as in the actual installation.

b. Up to 10 m, interconnecting cable lengths in the setup shall be the same as in the actual installation.

c. If a cable is longer than 10 m in the actual installation, the cable length in the set up shall be between 10 m and the actual length.

d. The cable arrangement shall be such that it satisfies the following conditions:

1. At least the first 2 m (except for cables that are shorter in the actual installation) of each interconnecting cable associated with each enclosure of the EUT are run parallel to the front boundary of the setup.

2. Remaining cable lengths are routed to the back of the setup and placed in a zigzagged arrangement.

e. When the setup includes more than one cable, individual cables shall be separated by 2 cm measured from their outer circumference.

f. For bench top setups using ground planes, the cable closest to the front boundary shall be placed 10 cm from the front edge of the ground plane.

g. All cables shall be supported 5 cm above the ground plane (except for interconnecting cables between enclosures of the EUT that are higher in the actual installation).

5.3.6.6.3 Input power leads

a. Two metres of input power leads (including neutrals and returns) shall be routed parallel to the front edge of the setup in the same manner as the interconnecting leads.

b. Each input power lead, including neutrals and returns, shall be connected to a LISN.

c. Power leads that are bundled, as part of an interconnecting cable in the actual installation, shall be configured in the same fashion for the 2 m exposed length and then shall be separated from the bundle and routed to the LISN's.

d. After the 2 m exposed length, the power leads shall be terminated at the LISN's in such a manner that the total length of power lead from the EUT electrical connector to the LISN's shall not exceed 2.5 m.

e. All power leads shall be supported 5 cm above the ground plane.

f. If the power leads are twisted in the actual installation, they shall be twisted up to the LISN's

5.3.6.7 Electrical and mechanical interfaces

a. Either the actual equipment from the platform installation or loads that simulate the electrical properties (impedance, grounding, balance, and so forth) present in the actual installation shall terminate electrical input or output interfaces.

b. Signal inputs shall be applied to the electrical interfaces to exercise EUT circuitry.

c. EUT with mechanical outputs shall be loaded under expected conditions.

d. When variable electrical or mechanical loading is present in the actual installation, testing shall be performed under expected worst-case conditions.

e. When active electrical loading (such as a test set) is used, it shall be ensured that the active load meets the ambient requirements of 5.3.2 when connected to the setup, and that the active load does not respond to susceptibility signals.

f. Antenna ports on the EUT shall be terminated with shielded, matched loads if the RF link is not used during the test.

5.3.7 Operation of EUT

5.3.7.1 General

a. During emission measurements, the EUT shall be placed in the operating mode, which produces maximum emissions.

b. During susceptibility testing, the EUT shall be placed in its most susceptible operating mode.

c. When the EUT has several available modes (including software controlled operational modes), the number of modes to be tested for emission and susceptibility shall be such that all circuitry is evaluated.

NOTE It is expected that the customer defines or agrees operating modes.

5.3.7.2 Operating frequencies for tuneable RF equipment

Measurements shall be performed with the EUT tuned to not less than three frequencies within each tuning band, tuning unit, or range of fixed channels, consisting of one mid-band frequency and a frequency within ±5% from each end of each band or range of channels.

5.3.7.3 Operating frequencies for spread spectrum equipment

Operating frequency requirements for two major types of spread spectrum equipment shall be as follows:

a. frequency hopping: measurements are performed with the EUT utilizing a hop set which contains a minimum of 30% of the total possible frequencies, and the hop set is divided equally into three segments at the low, mid, and high end of the EUT operational frequency range,

b. direct sequence: measurements are performed with the EUT processing data at the highest possible data transfer rate.

5.3.7.4 Susceptibility monitoring

a. The EUT shall be monitored during susceptibility testing for indications of degradation or malfunction.

NOTE This monitoring is normally accomplished using built-in-test, visual displays, aural outputs, and other measurements of signal outputs and interfaces.

b. If EUT performance is monitored through installation of special circuitry in the EUT, the modifications shall not influence test results.

5.3.8 Use of measurement equipment

5.3.8.1 General

Any frequency selective measurement receiver can be used for performing the testing described in this standard if the receiver characteristics (that is sensitivity, selection of bandwidths, detector functions, dynamic range, and frequency of operation) meet the constraints specified in this standard and are sufficient to demonstrate compliance with the applicable limits.

5.3.8.2 Detector

a. A peak detector shall be used for all frequency domain emission and susceptibility measurements.

NOTE This device detects the peak value of the modulation envelope in the receiver pass band. Measurement receivers are calibrated in terms of an equivalent root mean square value of a sine wave that produces the same peak value.

b. When measurement devices other than peak detector (e.g. oscilloscopes, non-selective voltmeters, or field strength sensors) are used for susceptibility testing, correction factors shall be determined and applied for test signals to adjust the reading to equivalent RMS values under the peak of the modulation envelope.

5.3.8.3 Calibration fixture (jig)

When current measurements are performed on the central line of a coaxial transmission line a transmission line with 50 Ω characteristic impedance, coaxial connections on both ends, and space for an injection probe around the centre conductor shall be used for calibration.

NOTE 0 Figure 5-4 represents an arrangement described in MIL-STD-461E.

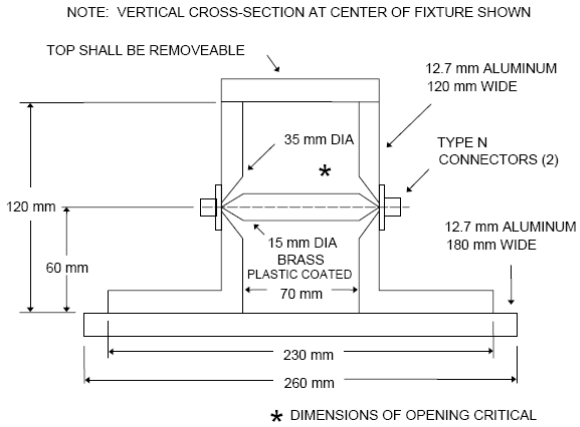

Figure 5-4: Typical calibration fixture

5.3.9 Emission testing

5.3.9.1 Bandwidths

a. The measurement receiver bandwidths listed in Table 5-2 shall be used for emission testing.

NOTE These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers.

b. Video filtering shall not be used to bandwidth limit the receiver response.

c. If a controlled video bandwidth is available on the measurement receiver, it shall be set to its greatest value.

d. If receiver bandwidths larger that those in Table 5-2 are used, no bandwidth correction factors shall be applied to test data due to the use of larger bandwidths.

NOTE Larger bandwidths can result in higher measured emission levels.

Table 5-2: Bandwidth and measurement time

Frequency Range	6 dB bandwidth	Dwell time	Minimum measurement time (analogue measurement receiver)
30 Hz - 1 kHz	10 Hz	0.15 s	0.015 s/Hz
1 kHz - 10 kHz	100 Hz	0.015 s	0.15 s/kHz
10 kHz - 150 kHz	1 kHz	0.015 s	0.015 s/kHz
150 kHz - 30 MHz	10 kHz	0.015 s	1.5s/MHz
30 MHz - 1 GHz	100 kHz	0.015 s	0.15s/MHz
Above 1 GHz	1 MHz	0.015 s	15 s/GHz

5.3.9.2 Emission identification

All emissions regardless of characteristics shall be measured with the measurement receiver bandwidths specified in Table 5-2.

5.3.9.3 Frequency scanning

a. For emission measurements, the entire frequency range for each test shall be scanned.

b. Minimum measurement time for analogue measurement receivers during emission testing shall be as specified in Table 5-2.

c. Synthesized measurement receivers shall step in one-half bandwidth increments or less, and the measurement dwell time shall be as specified in Table 5-2.

d. For equipment that operates, such that potential emissions are produced at only infrequent intervals, times for frequency scanning shall be increased such than any emission is captured.

5.3.9.4 Emission data presentation

a. Amplitude versus frequency profiles of emission data shall be automatically generated and displayed at the time of the test.

b. Except for verification of the validity of the output, data shall not be gathered manually.

c. The information shall be displayed after application of correction factors, including transducers, attenuators, and cable loss.

d. Data output of the EUT test result shall be in the form of amplitude over time (for the time domain plots) and amplitude over frequency (for frequency domain plots), superimposed with the EMI test limit.

e. Units of measurement for frequency domain emissions measurements shall be reported in units of dB referenced to 1 µV, 1 µA, 1 µV/m, 1 pT depending on the unit defined in the test limit.

f. For time domain measurements, oscilloscope plots shall include the amplitude physical unit (V ou A) conversion factors V into A if not done automatically by the oscilloscope, and the oscilloscope sensitivity, time base settings and measurement bandwidth.

g. For frequency domain plots, emission data shall be reported in graphic form with frequency resolution of 1 percent, or twice the measurement receiver bandwidth, whichever is less stringent.

h. In the event of any emissions test result over the emission test limit above 100 MHz, greater accuracy of its frequency shall be reported with resolution better than or equal to twice the measurement bandwidth.

i. Each plot of emission data shall be reported with a minimum amplitude resolution of 1 dB.

5.3.10 Susceptibility testing

5.3.10.1 Frequency stepping

a. For susceptibility measurements, the entire frequency range for each applicable test shall be scanned.

NOTE Stepped scans refer to signal sources that are sequentially tuned to discrete frequencies.

b. Stepped scans shall dwell at each tuned frequency for the greatest of three seconds or the EUT response time.

NOTE Ten frequency steps per decade can be used as a basis.

c. Step sizes shall be decreased such to permit observation of a response.

NOTE For receivers, it can make use of the frequency plan to adjust the number of points.

5.3.10.2 Modulation of susceptibility signals

a. Susceptibility test signals shall be pulse modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle for susceptibility signals at a frequency larger than 100 kHz.

b. CW test signals shall be used for susceptibility signals at a frequency smaller than 100 kHz.

5.3.10.3 Thresholds of susceptibility

When susceptibility indications are noted in EUT operation, a threshold level shall be determined as follows where the susceptible condition is no longer present:

a. When a susceptibility condition is detected, reduce the interference signal until the EUT recovers.

b. Reduce the interference signal by an additional 6 dB.

c. Gradually increase the interference signal until the susceptibility condition reoccurs. The resulting level is the threshold of susceptibility.

d. Record this level, frequency range of occurrence, frequency and level of greatest susceptibility, and the other test parameters..

5.3.10.4 Susceptibility data presentation

a. The susceptibility criteria defined in the EMI test procedure shall be repeated in the test report, or the “as run” EMI test procedure shall be an annex to the EMI test report.

b. Data showing the frequencies and amplitudes at which the test was conducted shall be provided in graphical or tabular form.

c. Indications of compliance with the requirements shall be provided.

NOTE Such indications can be provision of oscilloscope plots of injected waveforms with test data

d. Information shall be displayed after application of correction factors, including transducers, attenuators, and cable loss.

e. Data shall be reported with frequency resolution of 1 percent,

f. Data shall be provided with a minimum amplitude resolution of 1 dB for each plot.

g. If susceptibility is observed, determined levels of susceptibility shall be recorded in the test report

5.3.11 Calibration of measuring equipment

5.3.11.1 General

Measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every two years or when damaged.

5.3.11.2 Measurement system test

a. At the start of each emission test, the complete test system (including measurement receivers, cables, attenuators, couplers, and so forth) shall be verified by injecting a known signal (as stated in the individual test procedure), while monitoring system output for the proper indication.

b. When the emission test involves an uninterrupted set of repeated measurements (such as evaluating different operating modes of the EUT) using the same measurement equipment, the measurement system test may be accomplished only one time.

5.4 System level

5.4.1 General

Each item of equipment and subsystem shall have successfully passed functional acceptance test procedures as installed on the platform, prior to system level EMC test.

5.4.2 Safety margin demonstration for critical or EED circuits

a. A test performed to demonstrate compliance with the safety margin requirement shall use one or more of the following test approaches:

   1. Inject interference at critical system points at x dB higher level than exists, while monitoring other system points for improper responses, where x = EMISM.

   2. Measure the susceptibility of critical system circuits for comparison to existing interference levels, to determine the margin.

   3. Sensitize the system to render it x dB more susceptible to interference, while monitoring for improper response, where x = EMISM.

b. Safety margin demonstration for something that is susceptible to a time domain circuit (including EED's) shall use time domain methods.

5.4.3 EMC with the launch system

a. If the spacecraft is not powered during launch, EMC test with the launch system need not be performed.

b. If the spacecraft is powered during launch, the electric field radiation, including intentional transmission, shall be measured at locations specified in the Launcher User's Manual

c. In case of a transmitting spacecraft under fairing, the EMISM applied to EED's shall be verified.

5.4.4 Lightning

Lightning protection specified in ECSS-E20, clause 6.3.2.3, shall be verified by analysis from equipment demonstration.

NOTE 1 Test at system level need not be performed.

NOTE 2 The bi-exponential model defined in clause 4.2.3.2 is generally used

5.4.5 Spacecraft and static charging

a. Material use, bonding of discharge elements, thermal blankets, or metallic items using a bond for static potential equalization shall be verified by inspection or measurement at assembly into structure.

b. If the bond is only used for charging control, the bonding resistance shall be measured with a dc-current in the range 10 to 100 μA, under only one polarity, with a 2-wires ohmmeter

NOTE If the bond is only used for charging control the clauses 5.4.10.5.4.10a and 5.4.10.5.4.10b do not apply

5.4.6 Spacecraft DC magnetic field emission

Spacecraft DC magnetic field emission requirements shall be verified by a combination of analysis and tests.

5.4.7 Intra–system electromagnetic compatibility

a. For intra-system EMC tests, the support equipment shall provide the functionality of exercising culprits and victims, and include the support equipment instructions.

b. Wherever 0 dB EMISM is a requirement, functional tests at spacecraft level may be accepted as a verification of EMC.

5.4.8 Radiofrequency compatibility

a. Except for passive intermodulation products, radiofrequency compatibility shall be verified by a test at system level.

b. Absence of passive intermodulation products shall be verified in accordance with ECSS-E-20B, clause 7.4.

5.4.9 Grounding

The system-level electrical grounding and isolation shall be verified by isolation and continuity tests at system assembly.

NOTE The grounding and isolation design is documented by the system-level grounding diagram including EGSE.

5.4.10 Electrical bonding

a. Except for bonding used only for charging control, the bonding resistances shall be measured using a 4-wires method, under a pulsed DC current of 1A.

b. Except for bonding used only for charging control, the probes shall be reversed and re-measured to detect possible non linearities across the bonded junction.

NOTE See clause 5.4.55.4.5b

5.4.11 Wiring and shielding

Wiring category and cable shields shall be verified by review of design and inspection.

5.5 Equipment and subsystem level test procedures

5.5.1 General

Test procedures are specified in clauses 5.5.2 through 5.5.12 for verifying emission and susceptibility requirements at subsystem or equipment level. Table 5-3 gives the correspondence between procedures and recommended limits defined in Annex A

Table 5-3: Correspondence between test procedures and limits

Informative limit Annex A	Title of test procedure	Verification Section 5
A.2	CE on power leads, differential mode, 30 Hz to 100 kHz (1st part)	5.5.2
A.2	CE on power leads, differential mode, 100 kHz to 100 MHz (2nd part)	5.5.3
A.3	CE on power leads, in-rush currents	5.5.4
A.4	CE on power and signal leads, common mode, 100 kHz to 100 MHz	5.5.3
A.5	CE on antenna ports	Specific
A.6	DC magnetic field emission	5.5.5
A.7	RE, low-frequency magnetic field	Specific
A.8	RE, low-frequency electric field	Specific
A.9	RE, electric field, 30 MHz to 18 GHz	5.5.6
A.10	CS, power leads, differential mode, 30 Hz to 100 kHz.	5.5.7
A.11	CS, power and signal leads, common mode, 50 kHz to 100 MHz	5.5.8
0	CS, power leads, short spike transients	5.5.9
A.13	RS, magnetic field, 30 Hz to 100 kHz	5.5.10
A.14	RS, electric field, 30 MHz to 18 GHz	5.5.11
A.15	Susceptibility to electrostatic discharge	5.5.12

5.5.2 CE, power leads, differential mode, 30 Hz to 100 kHz

5.5.2.1 Purpose

This method is used for measuring conducted emissions in the frequency range 30 Hz to 100 kHz on all input power leads including returns.

5.5.2.2 Test equipment

The test equipment shall be as follows:

a. Measurement receiver

b. Current probe

c. Signal generator with amplifier

d. DC-current supply

e. Data recording device

f. Oscilloscope

g. Coaxial "T" connector and coaxial to bifilar transition

h. 1 Ω and 10 Ω power metal film resistors with inductance lower than 100 nH

i. LISN defined in 5.3.4

5.5.2.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as specified in 5.3.6 and Figure 5-3.

b. For measurement system check, configure the test setup as shown in Figure 5-5.

c. For equipment testing, configure the test setup as shown Figure 5-6.

5.5.2.4 Procedure

The test procedures shall be as follows:

a. Turn on the measurement equipment and wait until it is stabilized.

b. If the EMEVP specifies to check the measurement system, check it by evaluating the overall measurement system from the current probe to the data output device, as follows:

   1. Apply a calibrated signal level, at 1 kHz and 100 kHz, which is at least 6 dB below the emission limit to the current probe.

      NOTE A power amplifier can be necessary at 1 kHz.

   2. Apply through the current probe a DC-current equivalent to the EUT supply current.

      NOTE 1 A DC current is applied for verifying that the current probe will not be saturated by the EUT DC supply current.

      NOTE 2 This DC current is applied through the LISN for applying the same impedance through the probe as with the EUT.

   3. Verify the AC current level as measured with the probe by comparison with voltage across the 1 Ω resistor at 1 kHz and the 10 Ω resistor at 100 kHz; also, verify that the current waveform is sinusoidal.

4. Scan the measurement receiver for each frequency in the same manner as a normal data scan. Verify that the data-recording device indicates a level within ±3 dB of the injected level.

5. If readings are obtained which deviate by more than ±3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.

c. Test the EUT by determining the conducted emissions from the EUT input power leads, hot line and return, and measure the conducted emission separately on each power lead, as follows:

1. Turn on the EUT and wait for its stabilization.

2. Select a lead for testing and clamp the current probe into position.

3. Scan the measurement receiver over the frequency range, using the bandwidths and minimum measurement times specified in Table 5-2, clause 5.3.9.1.

4. Repeat 5.5.2.4.c.2 and 5.5.2.4.c.3 for each power lead.

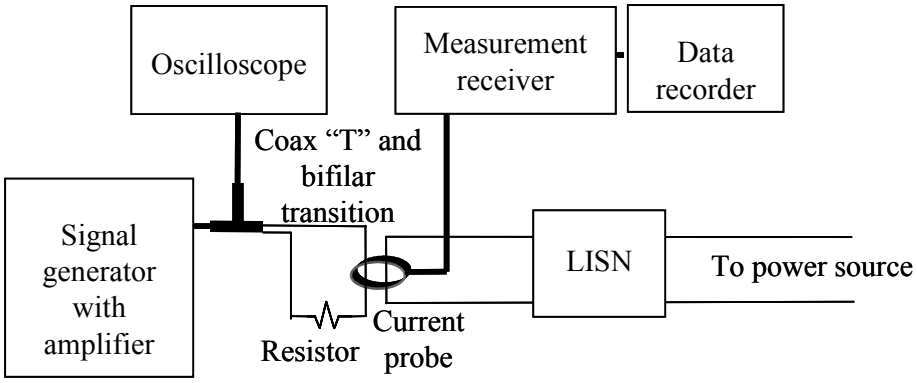

Figure 5-5: Conducted emission, 30 Hz to 100 kHz, measurement system check

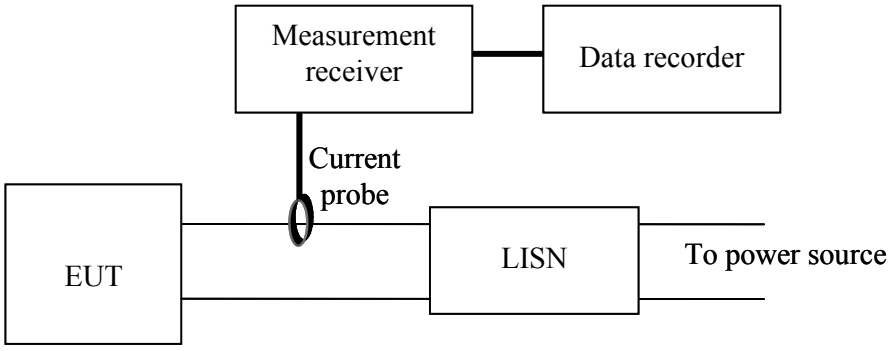

Figure 5-6: Conducted emission, 30 Hz to 100 kHz, measurement setup

5.5.3 CE, power and signal leads, 100 kHz to 100 MHz

5.5.3.1 Purpose

This test procedure is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads including returns, and for common mode emission.

5.5.3.2 Test equipment

The test equipment shall be as follows:

a. Measurement receiver

b. Current probe

c. Signal generator

d. Data recording device

e. Oscilloscope with 50Ω input

f. 50Ω power divider (6dB “T” connector)

g. 50Ω coaxial load

h. Calibration fixture defined in 5.3.8.3

i. LISN's defined in 5.3.4

5.5.3.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as specified in 5.3.6 and Figure 5-3.

b. Configure the test setup for the measurement system check as shown in Figure 5-7.

c. For compliance testing of the EUT:

   1. Configure the test setup as shown in Figure 5-8.

   2. Position the current probe 10 cm from the LISN.

5.5.3.4 Procedures

The test procedures shall be as follows:

a. Turn on the measurement equipment and wait until it is stabilized.

b. If the EMEVP specifies to check the measurement system, check it by evaluating the overall measurement system from the current probe to the data output device, as follows:

   1. Apply a calibrated signal level that is at least 6 dB below the applicable limit at 1 MHz and 10MHz or at a level allowing out of the noise reading on the oscilloscope, whatever is greater, to the current probe in the jig.

   2. Apply through the current probe using a second wire, a DC current equivalent to the EUT nominal supply current

      NOTE 1 A DC current is applied for verifying that the current probe will not be saturated by the EUT DC supply current.

      NOTE 2 This DC current is applied through the LISN for applying the same impedance through the probe as with the EUT.

3. Verify the AC current level, as measured with the probe by comparison with the voltage on the T derivation.
4. Scan the measurement receiver for each frequency in the same manner as a normal data scan, and verify that the data-recording device indicates a level within ±3 dB of the injected level.
5. If readings are obtained which deviate by more than ±3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.

c. Test the EUT by determining the conducted emission from the input power leads, hot lines and returns separately, and from each interconnecting bundle (common mode), including the ones with power leads, as follows:

1. Turn on the EUT and wait until it is stabilized.
2. Select a lead or a bundle for testing and clamp the current probe into position.
3. Scan the measurement receiver over the frequency range, using the bandwidths and minimum measurement times specified in Table 5-2, clause 5.3.9.1.
4. Repeat 5.5.3.4.c.2 and 5.5.3.4.c.3 for each power lead or for each bundle.

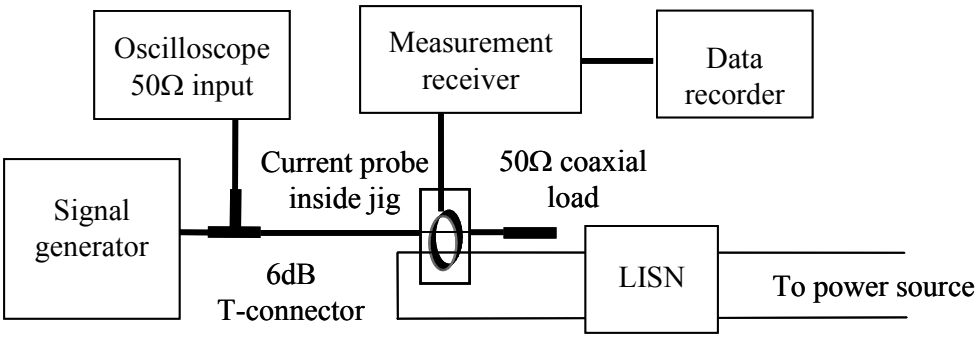

Figure 5-7: Conducted emission, measurement system check

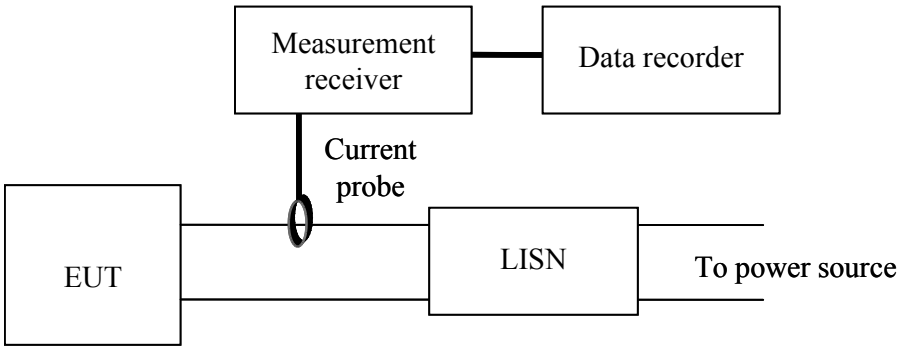

Figure 5-8: Conducted emission, measurement setup in differential mode

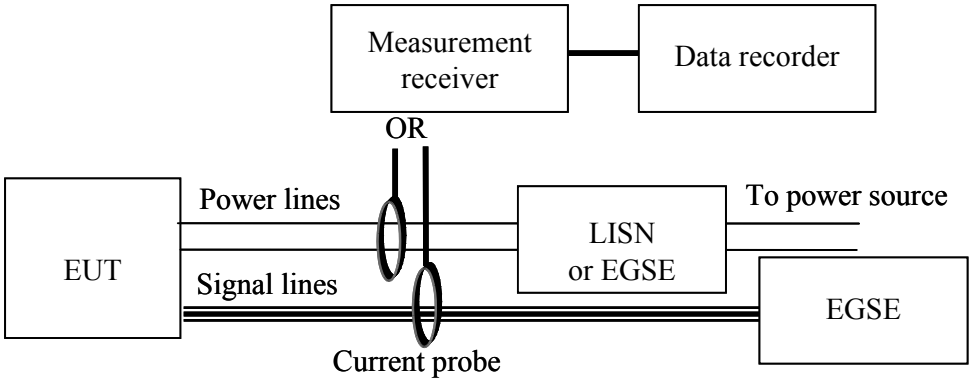

Figure 5-9: Conducted emission, measurement setup in common mode

5.5.4 CE, power leads, inrush current

5.5.4.1 Purpose

This test procedure is used to verify that the inrush current of the EUT does not exceed the specified requirements for power input leads.

5.5.4.2 Test equipment

The test equipment shall be as follows:

a. Two-channels oscilloscope

b. Current probe

c. Spike generator

d. Data recording device

e. Coaxial "T" connector

f. Coaxial to bifilar transition

g. 1 Ω power metal film resistor with inductance lower 30 nH and peak power capability.

h. LISN defined in 5.3.4.

i. Switching device, fast bounce-free power switch, or an actual power-controller except if the ON/OFF command is implemented in the EUT.

5.5.4.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as specified in 5.3.6 and Figure 5-3.

b. Configure the test setup for the measurement system check as shown in Figure 5-10.

c. Configure the test setup for compliance testing of the EUT as shown in Figure 5-11.

5.5.4.4 Procedures

The test procedures shall be as follows:

a. Turn on the measurement equipment and allow a sufficient time for stabilization.

b. If specified by the EMEVP, check the measurement system by evaluating the overall measurement system from the current probe to the data output device:

   1. Apply a calibrated spike that is at least 6 dB below the applicable limit to the current probe.

   2. Apply through the current probe a DC current equivalent to the EUT supply current

      NOTE 1 A DC current is applied for verifying that the current probe will not be saturated by the EUT DC supply current.

      NOTE 2 This DC current is applied through the LISN for applying the same impedance through the probe as with the EUT.

   3. Check the spike current as measured with the probe by comparison with the voltage across the resistor.

   4. Perform the measurement with the current probe on an oscilloscope in the same manner as for EUT testing and verify that the data-recording device indicates a level within ±3 dB of the injected level.

   5. If readings are obtained which deviate by more than ±3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.

c. Test the EUT by determining the conducted emission from the EUT input power leads, as follows:

   1. Select the positive lead for testing and clamp the current probe into position.

   2. Perform measurement by application of power on the EUT using a mercury relay (Figure 5-11.a), the internal EUT switch (Figure 5-11 b), or the power controller (Figure 5-11 c).

      NOTE The method for application of power is defined in the EMEVR

5.5.4.5 Data Presentation

a. In addition to 5.3.9.4, data presentation shall be a graphic output of current versus time displaying the transient characteristics with following conditions:

   1. amplitude resolution within 3% of the applicable limit

   2. time base resolution within 10% of rise time for measurement of rise and fall slopes

      NOTE Rise time is the duration between 10% and 90% of peak-to-peak amplitude

b. Two separate displays shall be provided showing respectively the initial rise time and the full inrush response

      NOTE Typica1 time bases are 10 µs full scale for the initial rise time and 1 ms full scale for the full inrush response

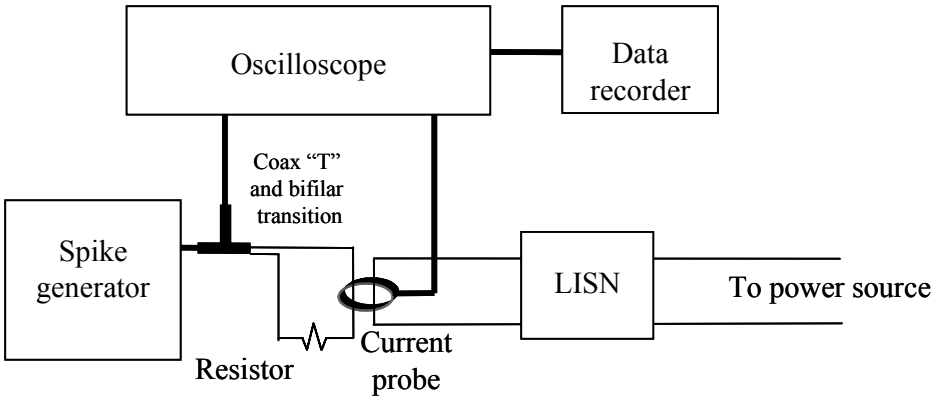

Figure 5-10: Inrush current: measurement system check setup

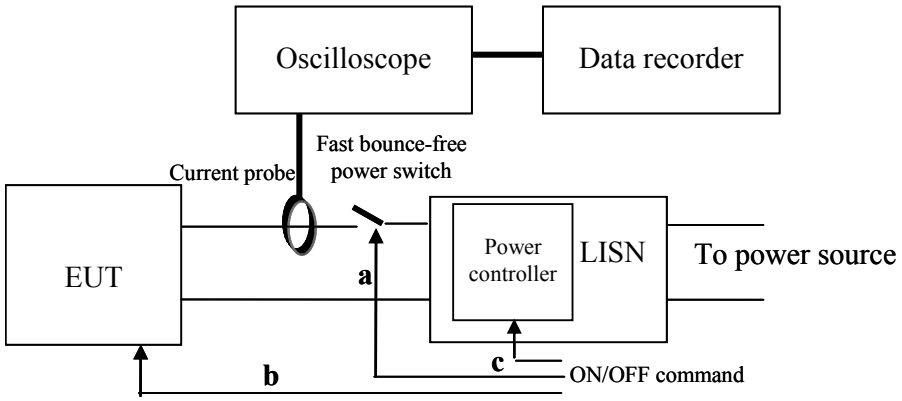

Figure 5-11: Inrush current: measurement setup

5.5.5 DC Magnetic field emission, magnetic moment

5.5.5.1 General

The described test method allows obtaining a rough estimate of the magnetic moment of the EUT (centred dipole approximation). It involves the constraint of measuring the magnetic field at distances typically more than three times the size of the EUT.

If a better model is needed, making it possible to predict the field at closer distances or more precisely than the centred dipole approximation allows, then either multiple dipole modelling techniques or spherical harmonics techniques shall be used.

NOTE It is the role of the EMCAB to assess the need for using such techniques, based on mission requirements.

5.5.5.2 Set-Up

a. The EUT should be set in an earth field compensated area providing zero-field conditions for the intrinsic moment determination.

NOTE 1 This is necessary in case the EUT contains a significant amount of soft magnetic material, as without earth field compensation an induced magnetic moment would appear.

NOTE 2 Earth field compensation is usually ensured by 2 or 3 sets of Helmholtz coils.

b. A right-handed orthogonal coordinate system XYZ shall be assigned to the EUT geometric centre.

c. The magnetic sensor (single-axis magnetometer) shall be installed successively on the 6 semi-axes at two different reference distances r_1 and r_2 from the geometric centre of the EUT and shall measure the field projection along these lines.

NOTE The reference distances are typically more than three times the size of the EUT

d. Alternatively the EUT may be installed on a turntable and rotated in front of a fixed magnetometer, presenting each XYZ axis (positive and negative) successively aligned with the sensor axis.

e. The magnetic field shall be positive when orientated from the centre of the EUT towards the magnetometer.

5.5.5.3 Test sequence

The test sequence shall be as follows:

a. EUT not operating, initial measurements on the six semi-axes at the reference distances.

b. Deperm:

1. EUT not operating, application of a deperming field in accordance with Figure 5-12 frequency 3 Hz, maximum amplitude between 4 000 and 5 000 µT, successively on each XYZ axis of the EUT.

NOTE 1 This is usually done using Helmholtz coils.

NOTE 2 A sequence of symmetrical sine periods of increasing and decreasing amplitude gives better results than a sine wave modulated by exponentials or ramp functions.

2. Measurement after deperm on the six semi-axes at the reference distances.

c. Perm:

1. EUT not operating, application of a perm field of 300 µT on each XYZ axis.

2. Measurement after perm on the six semi-axes at the reference distances.

d. Stray field: EUT operating, measurement on the six semi-axes at the reference distances.

e. Final deperm: repeat 5.5.5.3.b

5.5.5.4 Data presentation

For DC magnetic field emission, data shall be presented as follows, superseding clauses 5.3.9.4.5.3.9.4a through 5.3.9.4.5.3.9.4i:

a. For each measurement distance, for each of the 6 semi-axes, the following induction measurements in µT are plotted in tabular form:
$B_{(+X)}$, $B_{(-X)}$, $B_{(+Y)}$, $B_{(-Y)}$, $B_{(+Z)}$, $B_{(-Z)}$

b. For each measurement distance, mean inductions, for each axis, are computed in units of µT and plotted in tabular form, using following equations:

$$B_X = \frac{B_{(+X)} - B_{(-X)}}{2} \quad B_Y = \frac{B_{(+Y)} - B_{(-Y)}}{2} \quad B_Z = \frac{B_{(+Z)} - B_{(-Z)}}{2}$$

c. For each measurement distance r, 3-axes magnetic moment components in units of Am² are calculated using the following equations and reported:

$M_x = 5\ r^3\ B_X$ M in units of Am2, r in meters, B in µT
$M_y = 5\ r^3\ B_Y$
$M_z = 5\ r^3\ B_Z$

d. Using values of M_x, M_y and M_z at both distances r_1 and r_2, values M_1 and M_2 of the magnetic moment are calculated using the following equations and reported:

$$M_1 = \sqrt{M_x(r_1)^2 + M_y(r_1)^2 + M_z(r_1)^2}$$
$$M_2 = \sqrt{M_x(r_2)^2 + M_y(r_2)^2 + M_z(r_2)^2}$$

NOTE If the EUT is a centred dipolar source, then $M_1 = M_2$.

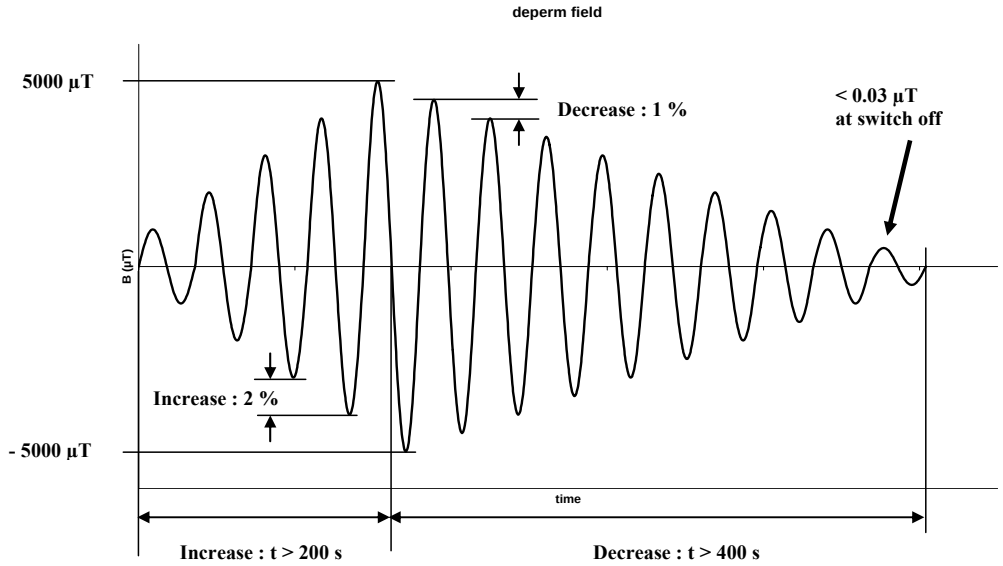

Figure 5-12: Smooth deperm procedure

5.5.6 RE, electric field, 30 MHz to 18 GHz

5.5.6.1 Purpose

This test procedure is used to verify that electric field emissions from the EUT and its associated cabling do not exceed specified requirements.

5.5.6.2 Test equipment

The test equipment shall be as follows:

a. Measurement receiver

b. Data recording device

c. Linearly polarized antennas

NOTE the following antennas are commonly used:

d. 30 MHz to 200 MHz, biconical, 137 cm tip to tip

e. 200 MHz to 1 GHz, double ridge horn, 69.0 by 94.5 cm opening, or log-periodic

f. 1 GHz to 18 GHz, double ridge horn, 24.2 by 13.6 cm opening

g. Signal generators

h. Stub radiator

i. LISN defined in 5.3.4, optional

5.5.6.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figure 5-3 and 5.3.6, and ensure that the EUT is oriented such that the surface that produces the maximum radiated emissions is toward the front edge of the test setup boundary.

NOTE The LISN should be used

b. Check the measurement system by configuring the test equipment as shown in Figure 5-13.

c. Test the EUT antenna positioning as follows:

1. Determine the test setup boundary of the EUT and associated cabling for use in positioning of antennas.

2. Use the physical reference points on the antennas shown in Figure 5-14 for measuring heights of the antennas and distances of the antennas from the test setup boundary, as follows:

(a) Position antennas 1 m from the front edge of the test setup boundary for all setups.

(b) Position antennas above the floor ground plane.

(c) Ensure that no part of any antenna is closer than 1 m from the walls and 0.5 m from the ceiling of the shielded enclosure.

3. Determine the antenna positions as follows:

(a) For testing below 200 MHz:

* For setups with the side edges of the boundary 3 m or less, one position, with the antenna centred with respect to the side edges of the boundary.
* For setups with the side edges of the boundary greater than 3 m, N antenna positions at spacing as shown in Figure 5-15, where N is the edge-to-edge boundary distance (in metres) divided by 3 and rounding up to an integer.

(b) For testing from 200 MHz up to 1 GHz, place the antenna in such a number of positions that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

(c) For testing at 1 GHz and above, place the antenna in such a number of positions that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB-beamwidth of the antenna.

5.5.6.4 Procedures

The test procedures shall be as follows:

a. Turn on the measurement equipment and wait until it is stabilized.

b. Verify that the ambient requirements specified in 5.3.2.3 are met and take plots of the ambient.

c. Check the measurement system as follows:

   1. Using the system check path of Figure 5-13, perform the following evaluation of the overall measurement system from each antenna to the data output device at the highest measurement frequency of the antenna:

      (a) Apply a calibrated signal level that is at least 6 dB below the limit (limit minus antenna factor) to the coaxial cable at the antenna connection point.

      (b) Scan the measurement receiver in the same manner as a normal data scan, and verify that the data-recording device indicates a level within ±3 dB of the injected signal level.

      (c) If readings are obtained which deviate by more than ±3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.

   2. Using the measurement path of Figure 5-13, perform the following evaluation for each antenna to demonstrate that there is electrical continuity through the antenna:

      (a) Radiate a signal using an antenna or stub radiator at the highest measurement frequency of each antenna.

      (b) Tune the measurement receiver to the frequency of the applied signal and verify that a received signal of appropriate amplitude is present.

      NOTE This evaluation is intended to provide a coarse indication that the antenna is functioning properly. There is no requirement to measure accurately the signal level.

d. Test the EUT by using the measurement path of Figure 5-13 and determining the radiated emissions from the EUT and its associated cabling, as follows:

   1. Turn on the EUT and wait until it is stabilized.

   2. Scan the measurement receiver for each applicable frequency range, using the bandwidths and minimum measurement times in 5.3.9.1

   3. Orient the antennas for both horizontally and vertically polarized fields.

   4. Repeat steps 5.5.6.4.d.2 and 5.5.6.4.d.3 for each antenna position determined under 5.5.6.3.5.5.6.3c.

5.5.6.5 Data Presentation

In addition to 5.3.9.4, data presentation shall provide a statement verifying the electrical continuity of the measurement antennas as determined in5.5.6.4.5.5.6.4c.2.

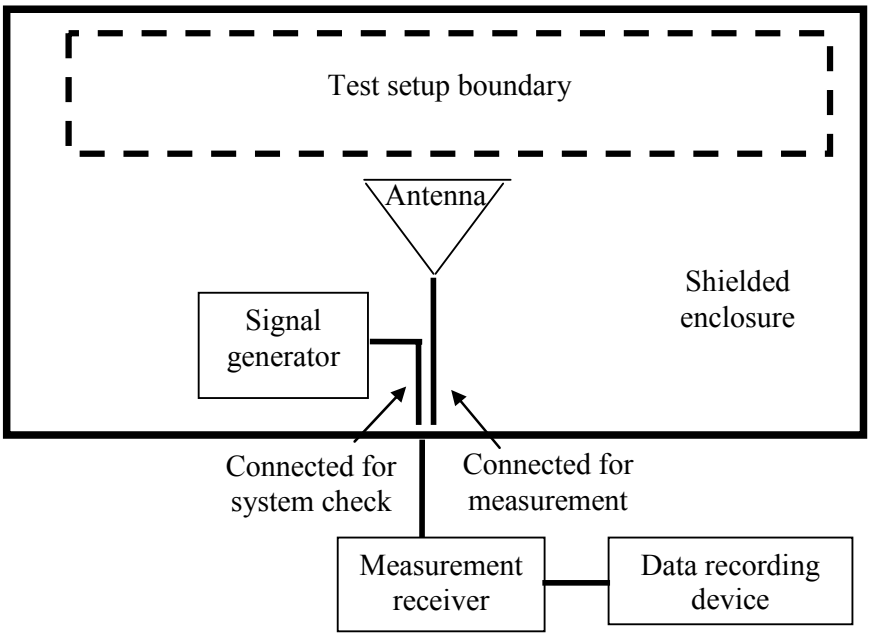

Figure 5-13: Electric field radiated emission. Basic test setup

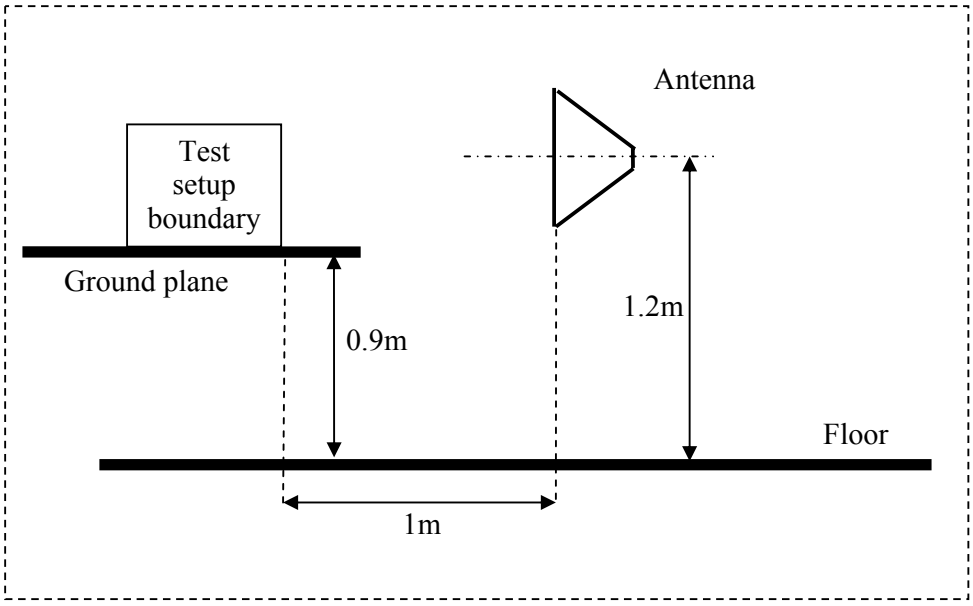

Figure 5-14: Electric field radiated emission. Antenna positioning

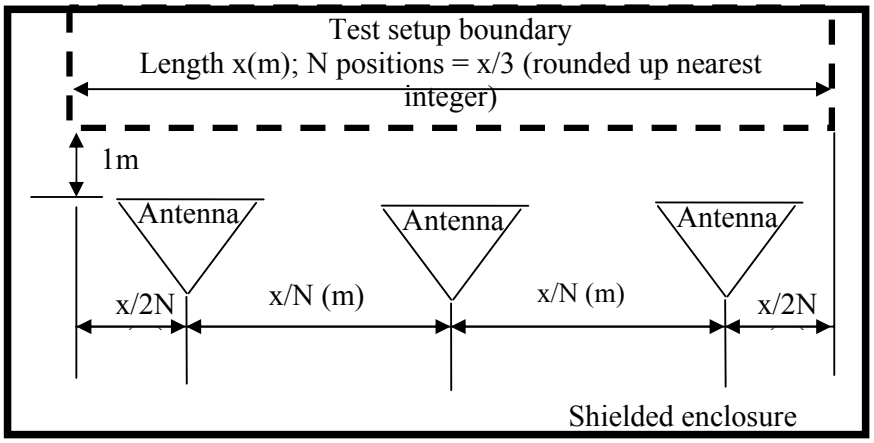

Figure 5-15: Electric field radiated emission. Multiple antenna positions

5.5.7 CS, power leads, 30 Hz to 100 kHz

5.5.7.1 Purpose

This test procedure is used to verify the ability of the EUT to withstand signals coupled on input power leads.

5.5.7.2 Test equipment

The test equipment shall be as follows:

a. Signal generator

b. Power amplifier

c. 1,5 to 2,7 Ω power metal film resistor with inductance lower 1000 nH and peak power capability

d. Oscilloscopes

e. Current probe

f. Differential high voltage-probe

g. injection transformer

h. LISN defined in 5.3.4, optional

5.5.7.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as specified in 5.3.6 and Figure 5-3.

b. Check measurement system by configuring the test equipment in accordance with Figure 5-16, and setting up the oscilloscope to monitor the voltage across the resistor.

c. Test the EUT by configuring the test equipment as shown in Figure 5-17.

5.5.7.4 Procedures

The test procedures shall be as follows:

a. Turn on the measurement equipment and wait until it is stabilized.

b. Check the measurement system using the measurement system check setup for waveform verification as follows:

   1. Set the signal generator to the lowest test frequency.

   2. Increase the applied signal until the oscilloscope indicates the voltage level specified by application of clause 4.2.8, verify that the output waveform is sinusoidal, and verify that the indication given by the current probe is within 3 dB of the expected level derived from the 1 Ω resistor voltage.

   3. Repeat 5.5.7.4.b.2 by setting the signal generator to the highest test frequency.

c. Test the EUT as follows:

   1. Turn on the EUT and wait until it is stabilized.

   2. Set the signal generator to the lowest test frequency, and increase the signal level until the testing voltage or current limit specified by application of clause 4.2.8, is reached on the power lead.

   3. Repeat 5.5.7.4.c.2 at all frequency steps through the testing frequency range.

   4. Evaluate the susceptibility as follows.

      (a) Monitor the EUT for degradation of performance.

      (b) If susceptibility is noted, determine the threshold level in accordance with 5.3.10.3.

   5. Repeat 5.5.7.4.c.2 to 5.5.7.4.c.4 for each power lead.

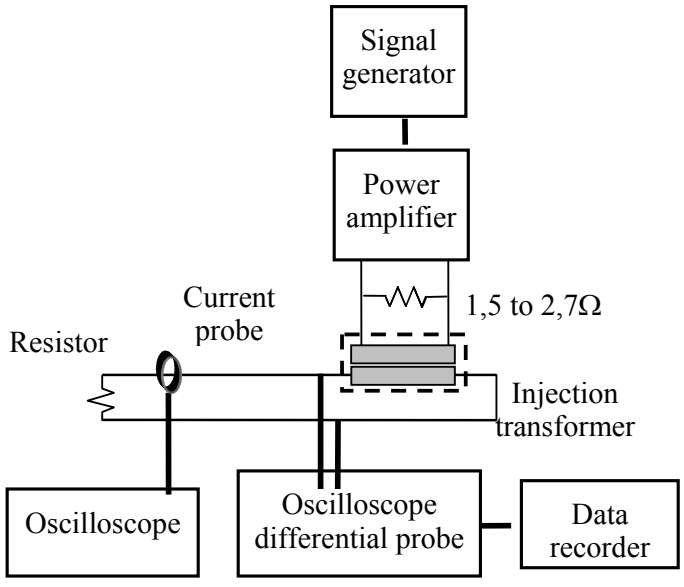

Figure 5-16: CS, power leads, measurement system check set-up

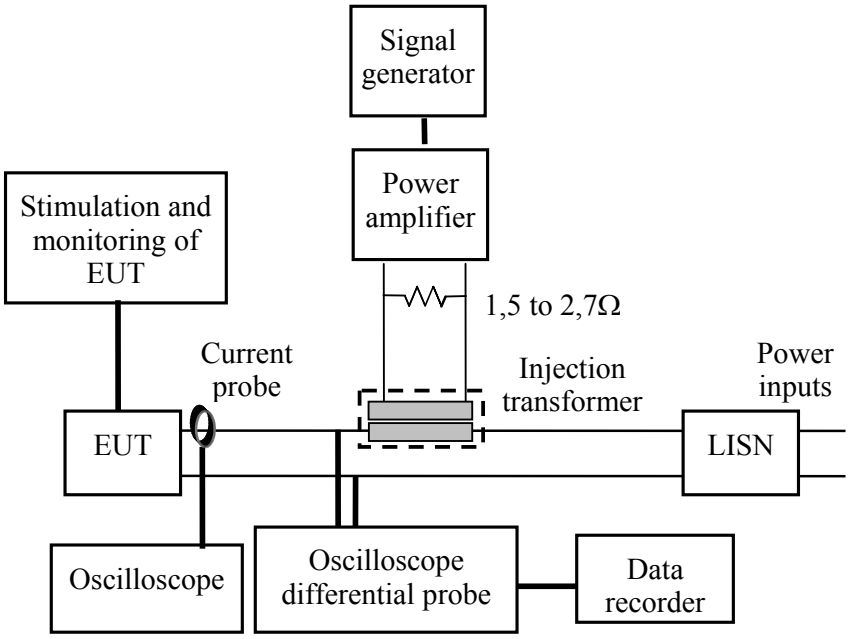

Figure 5-17: CS, power leads, signal injection

5.5.8 CS, bulk cable injection, 50 kHz to 100 MHz

5.5.8.1 Purpose

This test procedure is used to verify the ability of the EUT to withstand sinusoidal waves coupled on the EUT associated cables and power leads.

5.5.8.2 Test equipment

The test equipment shall be as follows:

a. Signal generator with amplitude or pulse modulation capability,

b. pulse generator, 1 kHz – 100 kHz, adjustable duty cycle,

c. power amplifier, 50 kHz – 100 MHz,

d. current injection probe, 50 kHz – 100 MHz,

e. current measurement probe, 50 kHz – 100 MHz,

f. one or two calibration fixture(s) (jigs) defined in 5.3.8.3,

g. one two-channels oscilloscope, 50 Ω input impedance,

h. waveform recording device,

i. 50 Ω coaxial load,

j. LISN defined in 5.3.4

k. spectrum analyzer (optional)

5.5.8.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in 5.3.6 and Figure 5-3.

b. For calibration:

   1. Configure the test equipment in accordance with Figure 5-18.
   2. Place the injection probe and the monitor probe around the central conductor of their respective jigs. The monitor probe and associated jig are optional.
   3. Terminate one end of the jig with a 50Ω-coaxial load and connect the other end to a 50 Ω-input oscilloscope.
   4. If a current monitor probe is used, connect it to another 50 Ω oscilloscope input.

c. For testing the EUT:

   1. Configure the test equipment as shown Figure 5-20.
   2. Place the injection and monitor probes around a cable bundle interfacing an EUT connector.
   3. Position the monitor probe:

d. 5 cm from the connector if the overall length of the connector and backshell does not exceed 5 cm.

e. at the overall length of the connector and backshell, otherwise.

   1. Position the injection probe 5 cm from the monitor probe.

5.5.8.4 Procedures

The test procedures shall be as follows:

a. Turn on the measurement equipment and wait until it is stabilized.

b. Calibrate the measurement system by performing the following procedures using the calibration setup :

   1. Set the frequency of the generator to 50 kHz and apply the pulse modulation, Figure 5-19.
   2. Increase the applied signal until the oscilloscope indicates the voltage specified by application of clause 4.2.8.
   3. Verify that both inputs of the oscilloscope, voltage monitored on 50 ohms and current monitored by the current probe, are consistent within 3 dB. This is applicable only if a current probe is used during calibration
   4. Record the generator settings
   5. Repeat 5.5.8.4.b.2 through 5.5.8.4.b.4 for each measurement frequency

c. Test the EUT by performing the following procedures, using the EUT test setup:

   1. Turn on the EUT and wait until it is stabilized.
   2. Select a bundle for testing and clamp the current probes into position.
      (a) Set the modulated sine generator to a test frequency, at low output level.
      (b) Adjust the modulation in duty cycle and frequency.

(c) Increase the generator output to the level determined during calibration, without exceeding the current limit specified by application of clause 4.2.8 and record the peak current obtained.

(d) Monitor the EUT for degradation of performance.

(e) If susceptibility is noted, determine the threshold level as measured by the current monitor probe in accordance with 5.3.10.3.

(f) Repeat 5.5.8.4c.2.(a) through 5.5.8.4.c.2.(e) for each test frequency

3. Repeat 5.5.8.4.c.2. applying the test signals to each bundle interfacing with each connector or all bundles taken together

d. The calibration need not be re-performed before testing each EUT bundle.

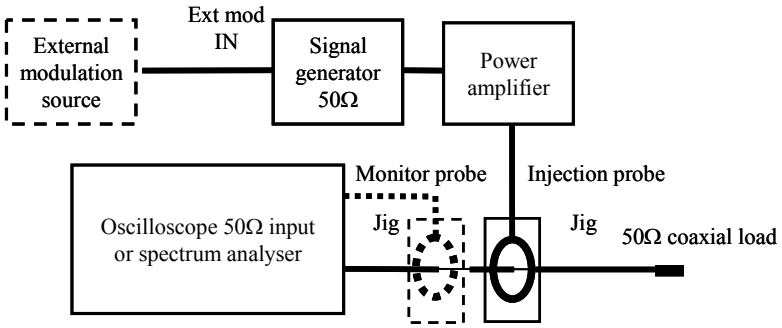

Figure 5-18: Bulk cable injection, measurement system check set-up

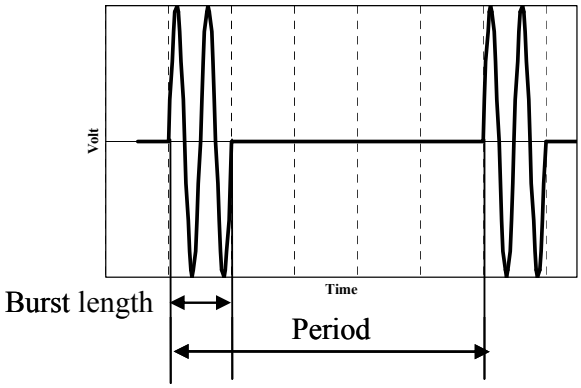

Figure 5-19: Signal test waveform

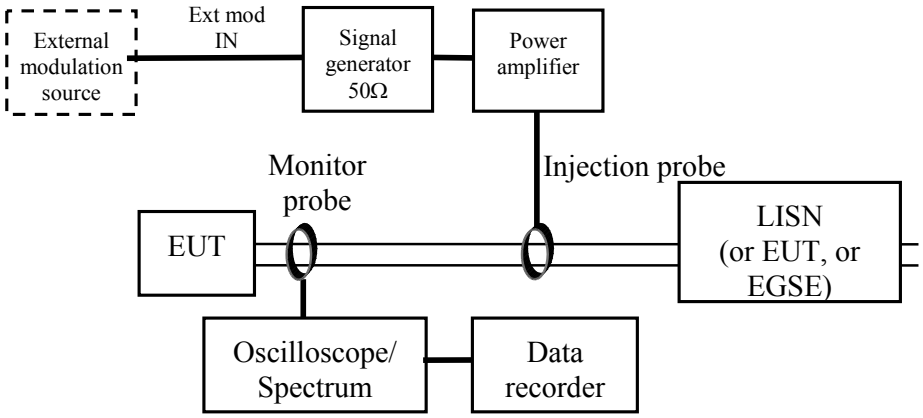

Figure 5-20: CS of power and signal leads, bulk cable injection

5.5.9 CS, power leads, transients

5.5.9.1 Purpose

This test procedure is used to verify the ability of the EUT to withstand short spikes coupled on EUT power leads, including grounds and returns that are not grounded internally to the equipment or subsystem.

5.5.9.2 Test equipment

The test equipment shall be as follows:

a. Spike generator with following characteristics:
   1. Pulse width of 10 µs and 0.15µs
   2. Pulse repetition rate capability up to 10 pulses per second
   3. Voltage output as required, positive then negative
   4. Output control
   5. Adequate transformer current capacity commensurate with line being tested
   6. Output impedance 5 Ω or less for 0.15 µs and 1 Ω or less for 10µs transient.
   7. External synchronization and triggering capability

b. Oscilloscope with 10 MHz bandwidth or greater.

c. Differential high-voltage probe

d. Isolation transformer

e. 5 Ω resistor power metal film resistor with inductance lower 100 nH and peak power capability

f. LISN defined in 5.3.4, with added inductor for a total inductance not less than 20 µH for parallel injection

5.5.9.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as specified in 5.3.6 and Figure 5-3.

b. For calibration:

   1. Configure the test equipment in accordance with Figure 5-21 for verification of the waveform.

   2. Set up the oscilloscope to monitor the voltage across the 5 Ω resistor.

c. For EUT testing configure the test equipment as shown in Figure 5-22 (series test method) or Figure 5-23 (parallel test method).

   NOTE With series injection, the internal LISN capacitor at the input power side is protecting the source.

   NOTE With parallel injection, the internal inductance is protecting the source, so a minimum value is needed as specified in 5.5.9.2.5.5.9.2f.

5.5.9.4 Procedures

The test procedures shall be as follows:

a. Turn on the measurement equipment and wait until it is stabilized.

b. Perform the following procedure using the calibration setup:

   1. Adjust the pulse generator for the pulse width, and pulse repetition rate

   2. Adjust the amplitude of the signal to the level specified in associated limit.

   3. Verify that the waveform complies with the requirements, if not, correct accordingly.

   4. Record the pulse generator amplitude setting.

c. Test the EUT by performing the following procedure using the test setup:

   1. Turn on the EUT and wait until it is stabilized.

   2. Adjust the spike generator to a pulse duration.

   3. Apply the test signal to each power lead and increase the generator output level to provide the specified voltage without exceeding the pulsed amplitude setting recorded during calibration.

   4. Apply repetitive (6 to 10 pulses per second) positive spikes to the EUT ungrounded input lines for a period not less than 2 minutes in duration, and if the equipment employ gated circuitry, trigger the spike to occur within the time frame of the gate.

   5. Repeat 5.5.9.4.c.4 with negative spikes.

   6. Monitor the EUT for degradation of performance.

   7. If susceptibility is noted, determine the threshold level in accordance with 5.3.10.3 and verify that it is above the specified requirements.

   8. Record the peak current as indicated on the oscilloscope.

   9. Repeat 5.5.9.4.c.2 through 5.5.9.4.c.8 on each power lead.

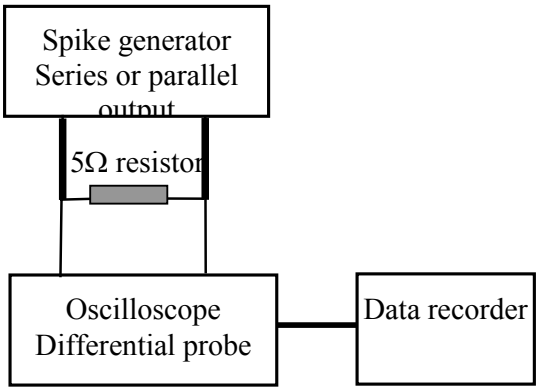

Figure 5-21: CS of power leads, transients, calibration set-up

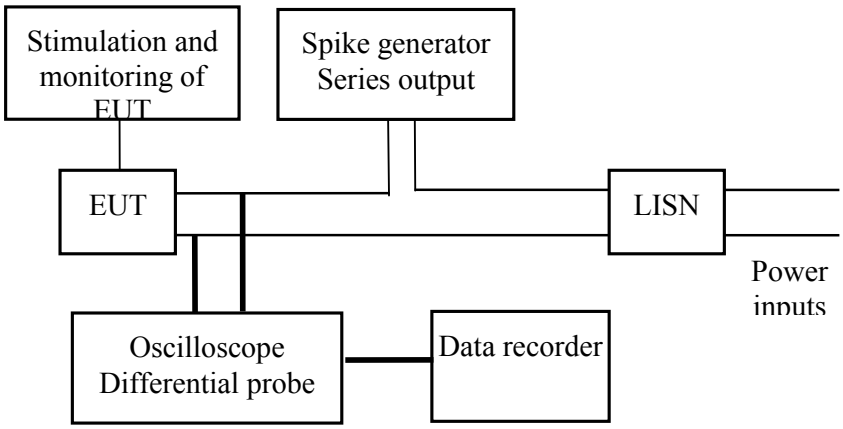

Figure 5-22: CS of power leads, spike series injection test setup

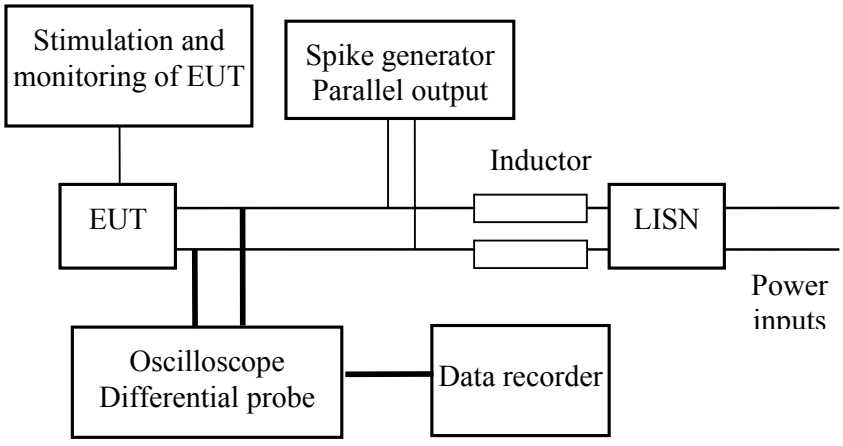

Figure 5-23: CS of power leads, spike parallel injection test setup

5.5.10 RS, magnetic field, 30 Hz to 100 kHz

5.5.10.1 Purpose

This test procedure is used to verify the ability of the EUT to withstand radiated magnetic fields.

5.5.10.2 Test Equipment

The test equipment shall be as follows:

a. Signal source

b. Power amplifier

c. Radiating loop having the following specifications:

   1. Diameter: 12 cm
   2. Number of turns: 20
   3. Wire: N°12 AWG, insulated copper
   4. Magnetic flux density: $9{,}5\times10^{7}$ pT/A of applied current at a distance of 5 cm from the plane of the loop.

d. Loop sensor having the following specifications:

   1. Diameter: 4 cm
   2. Number of turns: 51
   3. Wire: 7-41 Litz wire (7 strands, N°41 AWG)
   4. Shielding: electrostatic
   5. Correction Factor: manufacturer's data for factors to convert measurement receiver readings to decibels above one picotesla (dBpT)

e. Measurement receiver

f. Calibration fixture: coaxial transmission line with 50Ω characteristic impedance, coaxial connections on both ends, and space for a current probe around the centre

g. Current probe

h. LISN

5.5.10.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as specified in Figure 5-3 and 5.3.6.

b. Check the measurement system by configuring the measurement equipment, the radiating loop, and the loop sensor as shown in Figure 5-24.

c. Test the EUT by configuring the test setup as shown in Figure 5-25.

5.5.10.4 Procedures

The test procedures shall be as follows:

a. Turn on the measurement equipment and wait until it is stabilized.

b. Perform the following procedure using the calibration setup for verification of levels.

1. Set the signal source to a frequency of 1 kHz and adjust the output to provide a magnetic flux density of 110 dBpT as determined by the reading obtained on measurement receiver A and the relationship given in 5.5.10.2.5.5.10.2c.4.
2. Measure the voltage output from the loop sensor using measurement receiver B.
3. Verify that the output on measurement receiver B is within ±3 dB of the expected value based on the antenna factor and record this value.

c. Test the EUT by performing the following procedures for determination of location and level of susceptibility.

1. Turn on the EUT and wait until it is stabilized.
2. Select test frequencies as follows:
   (a) Locate the loop sensor 5 cm from the EUT face or electrical interface connector being probed and orient the plane of the loop sensor parallel to the EUT faces and parallel to the axis of connectors.
   (b) Supply the loop with such a current to produce magnetic field strengths at least 10 dB greater than the limit specified by application of clause 4.2.8 but not to exceed 15 A (183 dBpT).
   (c) Scan the frequency range.
   (d) If susceptibility is noted, select no less than three test frequencies per octave at those frequencies where the maximum indications of susceptibility are present.
   (e) Reposition the loop successively to a location in each 30 by 30 cm area on each face of the EUT and at each electrical interface connector, and repeat 5.5.10.4.c.2.(c) and 5.5.10.4.c.2.(d) to determine locations and frequencies of susceptibility.
   (f) From the total frequency data where susceptibility was noted in 5.5.10.4.c.2.(c) through 5.5.10.4.c.2.(e), select three frequencies per octave over the frequency range.
3. At each frequency determined in 5.5.10.4.c.2(f) apply a current to the radiating loop that corresponds to the specified limit, move the loop to search for possible locations of susceptibility without omitting the locations determined in 5.5.10.4.c.2(e) while maintaining the loop 5 cm from the EUT surface or connector, and verify that susceptibility is not present.

5.5.10.5 Data Presentation

In addition to 5.3.10.4, data presentation shall provide:

a. Tabular data showing verification of the radiating loop in 5.5.10.4.5.5.10.4b

b. Tabular data, diagrams, or photographs showing the locations and test frequencies determined in 5.5.10.4.5.5.10.4c.2(e) and 5.5.10.4.5.5.10.4c.2(f).

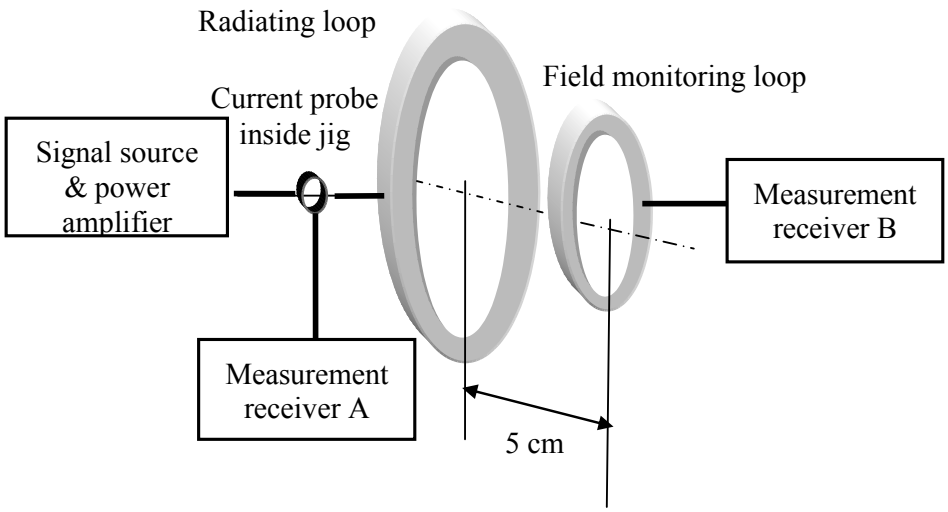

Figure 5-24: Measurement system check configuration of the radiating system

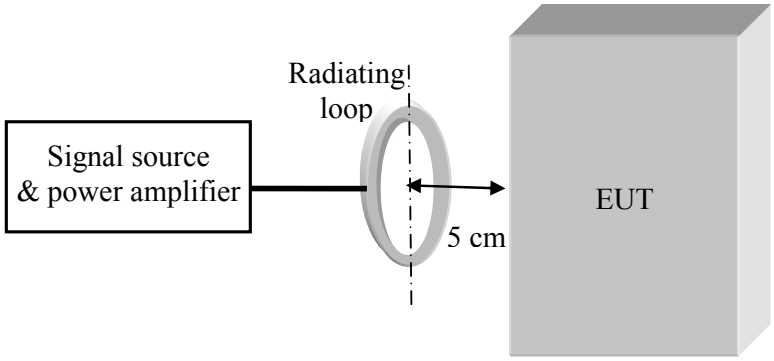

Figure 5-25: Basic test set-up

5.5.11 RS, electric field, 30 MHz to 18 GHz

5.5.11.1 Purpose

This test procedure is used to verify the ability of the EUT and associated cabling to withstand electric fields.

NOTE Additional requirements can apply beyond 18 GHz if SHF or EHF payloads are present. These are beyond the scope of the present standard.

5.5.11.2 Test equipment

The test equipment shall be as follows:

a. Signal generators

b. Power amplifiers

c. Receive antennas

1. under 1 GHz, not applicable
2. 1 GHz to 18 GHz, double ridge horn, 24.2 by 13.6 cm opening,

NOTE Above 1 GHz receive antennas may be not used, see 5.5.11.3.5.5.11.3b.2

d. Linearly polarized transmit antennas

NOTE The following antennas are commonly used:

e. 30 MHz to 200 MHz, biconical, 137 cm tip to tip

f. 200 MHz to 1 GHz, double ridge horn, 69.0 by 94.5 cm opening, or log-periodic

g. 1 GHz to 18 GHz, double ridge horn, 24.2 by 13.6 cm opening

h. Electric field sensors (physically small - electrically short)

i. Measurement receiver

j. Power meter

k. Directional coupler

l. Attenuator

m. Data recording device

n. LISN defined in 5.3.4, optional

5.5.11.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and specified in 5.3.6. and Figure 5-3.

NOTE The LISN should be used

b. For measurement system check, use following sensors

1. Electric field sensors from 30 MHz to 1 GHz.
2. Either receive antennas or electric field sensors above 1 GHz

NOTE For the electric sensors and receiving antennas to be used, see 5.5.11.2.5.5.11.2c and 5.5.11.2.5.5.11.2h.

c. Configure test equipment as specified in Figure 5-26.

d. Check the measurement system as follows:

1. Place the electric field sensors 1 m from, and directly opposite, the transmit antenna as shown Figure 5-27 and a minimum of 30 cm above the ground plane, not directly at corners or edges of EUT.
2. Place the receive antennas prior to placement of the EUT, as shown Figure 5-28, on a dielectric stand at the position and height above the ground plane where the centre of the EUT will be located.

e. For testing EUT:

1. Place the transmit antennas 1 m from the test setup boundary as follows:

(a) 30 MHz to 200 MHz

* For test setup boundaries ≤ 3 m (including all enclosures of the EUT and the 2 m of exposed interconnecting and power leads specified in 5.3.6.6.), center the antenna between the edges of the test setup boundary, ensuring that the interconnecting leads

represent the actual platform installation and are shorter than 2 m.

* For test setup boundaries > 3 m, use multiple antenna positions (N) at spacings as specified in Figure 5-27, where the number of antenna positions (N) is determined by dividing the edge-to-edge boundary distance (in metres) by 3 and rounding up to an integer.

(b) 200 MHz and above.
Use multiple antenna positions (N) as shown Figure 5-28, where the number of antenna positions (N) is determined as follows:

* For testing from 200 MHz up to 1 GHz, place the antenna in a number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna

* For testing at 1 GHz and above, place the antenna in a number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

2. Maintain the placement of electric field sensors as specified in 5.5.11.3.d.1 above.

5.5.11.4 Procedures

The test procedures shall be as follows:

a. Turn on the measurement equipment and EUT and wait until it is stabilized.

NOTE It is important at this point to assess the test area for potential RF hazards and take precautionary steps to assure safety of test personnel and fire avoidance.

b. Check and calibrate the measurement system, as follows:

1. Procedure when using electric field sensors:

(a) Record the amplitude shown on the electric field sensor display unit due to EUT ambient.

(b) Reposition the sensor until the level measured in (a) above is < 10% of the field strength to be used for testing.

2. Procedure when calibrating with the receive antenna:

(a) Connect a signal generator to the coaxial cable at the receive antenna connection point (antenna removed), set the signal source to an output level of 0 dBm at the highest frequency to be used in the present test setup and tune the measurement receiver to the frequency of the signal source.

(b) Verify that the output indication is within ±3 dB of the applied signal, considering all losses from the generator to the measurement receiver and, if deviations larger than 3dB are found, locate the source of the error and correct the deficiency before proceeding.

(c) Connect the receive antenna to the coaxial cable as specified in Figure 5-28, set the signal source to 1 kHz pulse modulation, 50% duty cycle, establish an electric field at the test frequency by using a transmitting antenna and amplifier, and gradually increase the electric field level until it reaches the limit specified by application of clause 4.2.8.

(d) Scan the test frequency range and record the input power levels to the transmit antenna to maintain the required field.

(e) Repeat procedures 5.5.11.4.b.2.(a) through 5.5.11.4.b.2.(d) whenever the test setup is modified or an antenna is changed.

NOTE The ground plane tends to short-circuit horizontally polarized fields, so that more power is needed to achieve the same field value in horizontal polarization as in vertical polarization.

c. Test the EUT as follows:

1. Procedure when using electric field sensors:

(a) Establish an unmodulated electric field at the test start frequency by using an amplifier and transmit antenna, and gradually increase the electric field level until it reaches the limit specified by application of clause 4.2.8.

(b) Set the signal source to 1 kHz pulse modulation, 50% duty cycle and apply the modulation

(c) Repeat the test at all frequency tests while maintaining field strength levels in accordance with the associated limit, and monitor EUT performance for susceptibility effects.

2. Procedure when calibrating with the receive antenna:

(a) Remove the receive antenna and reposition the EUT in conformance with 5.5.11.3.5.5.11.3e.

(b) Set the signal source to 1 kHz pulse modulation, 50% duty cycle, establish an electric field at the test start frequency by using an amplifier and transmit antenna, and gradually increase the input power level until it corresponds to the level recorded during the calibration routine.

(c) Repeat the test at all test frequencies while assuring the transmitter input power is adjusted in accordance with the calibration data collected, and constantly monitor the EUT for susceptibility conditions.

3. If susceptibility is noted, determine the threshold level in accordance with 5.3.10.3.

4. Perform testing over the frequency range with the transmit antenna vertically polarized, and repeat the testing with the transmit antenna horizontally polarized.

NOTE The settings needed to achieve the specified field level in vertical polarization are reused as is for the test in horizontal polarization.

5. Repeat 5.5.11.4.c.4 for each transmit antenna position determined in 5.5.11.3.e.

5.5.11.5 Data presentation

In addition to 5.3.10.4 , data presentation shall provide:

a. graphical or tabular data listing (receive antenna procedure only) all calibration data collected to include input power requirements used versus frequency, and results of system check in 5.5.11.4.5.5.11.4b.2(c) and 5.5.11.4.5.5.11.4b.2(d).

b. the correction factors used to adjust sensor output readings for equivalent peak detection of modulated waveforms.

c. diagrams or photographs showing actual equipment setup and the associated dimensions.

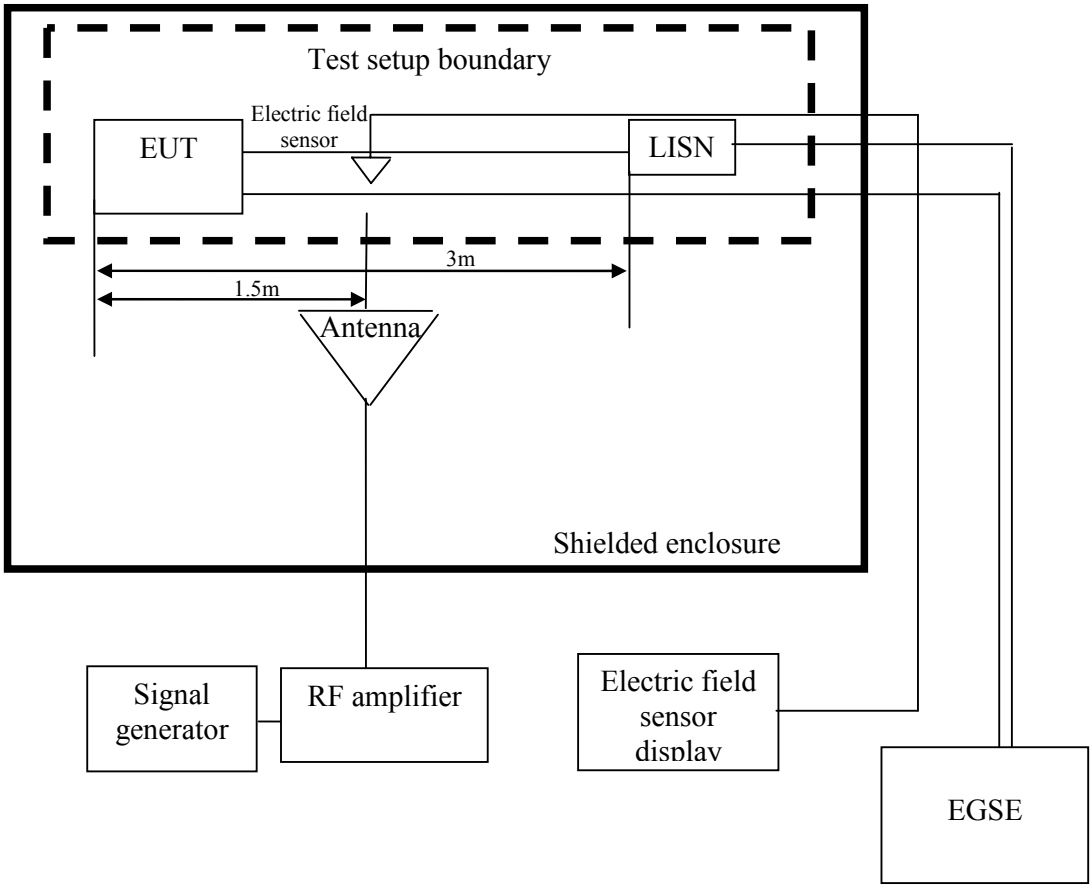

Figure 5-26: Test equipment configuration

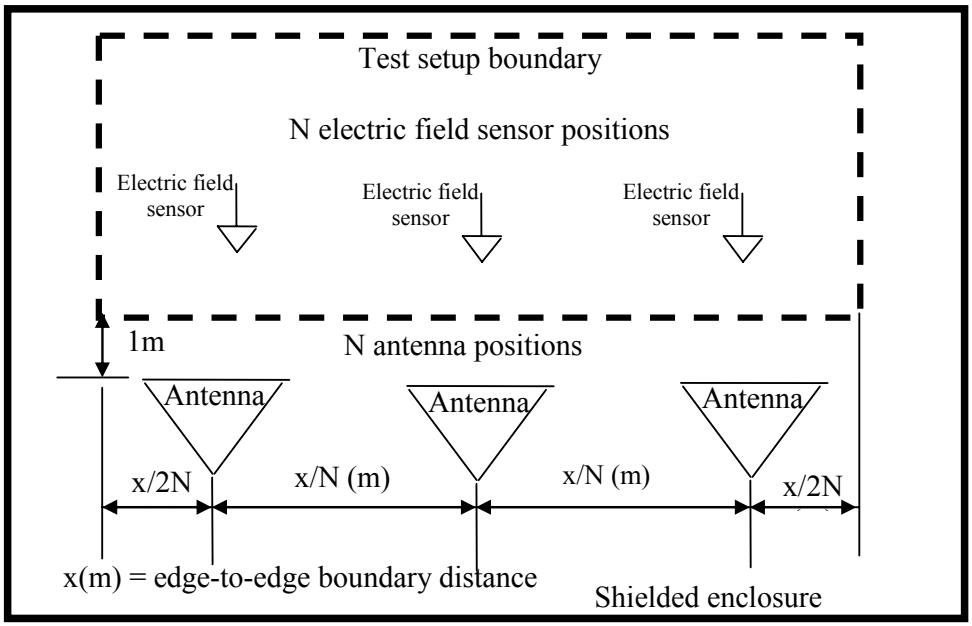

Figure 5-27: RS Electric field. Multiple test antenna positions

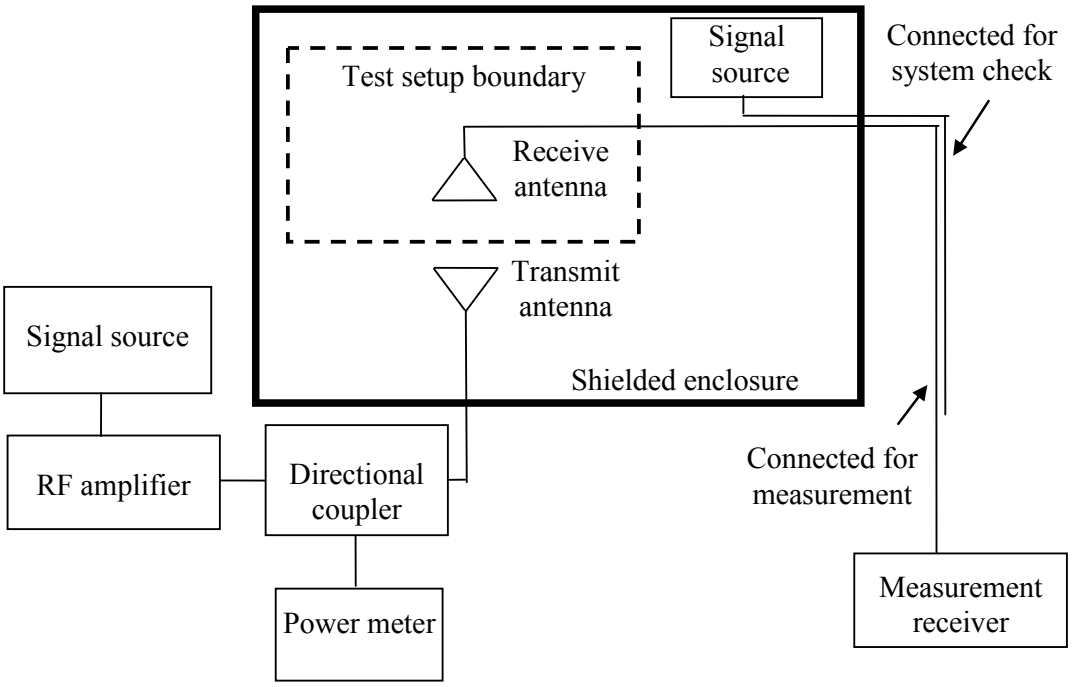

Figure 5-28: Receive antenna procedure

5.5.12 Susceptibility to electrostatic discharges

5.5.12.1 Overview

The purpose of this test is to determine the existence of susceptibility to electromagnetic effects of electrostatic discharges.

5.5.12.2 Test equipment

The test equipment shall be as follows:

a. DC high voltage supply or an ESD generator as specified in IEC 61000-4-2-(Edition 1.2).

NOTE Use of the ESD generator is less hazardous than use of the DC high voltage supply for test operators.

b. The discharge primary circuit is constituted of:

1. 6kV spark gap,

NOTE 1 An air spark gap or an overvoltage suppressor in a sealed pressurized envelop can be used.

NOTE 2 An air spark gap is less stable and has longer rise time.

2. 50 pF capacitance, high-voltage capacitor with inductance less than 20 nH,

3. 47 Ω damping resistor (high voltage specification),

NOTE The value can be adjusted at critical damping depending on value of capacitance C and self-inductance of the discharge circuit;

4. 10 kΩ resistors (high voltage specification).

NOTE Choke resistors prevent high-frequency components of discharge from flowing in uncontrolled paths so the discharge parameters are not dependent on length and position of high-voltage source wires.

c. Monitoring devices:

1. Two current probes, 100 A peak capability and more than 100 MHz bandwidth,

2. One high-voltage probe, 10 kV range, 1 MHz bandwidth,

NOTE If the probe input impedance is not high enough, it can prevent gap arcing by lowering the available voltage.

3. One two-channels digital oscilloscope with pretriggering capability.

NOTE Typical values are 100 ns pretrigger time, display window in the range 1 to 10 µs and resolution better than 4 ns.

5.5.12.3 Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as specified in 5.3.6. and Figure 5-3.

NOTE It is important at this point to assess the test area for potential high-voltage hazards and take necessary precautionary steps to assure safety of test personnel.

b. When using an ESD generator as a high-voltage power supply as shown Figure 5-30 or Figure 5-31, it is set in the contact discharge mode.

c. Connect the high-voltage electrode to the discharge circuit at the node between the spark gap and the capacitor.

d. The discharge circuit length is not larger than what is necessary to place in series the 20 cm long coupling wire, the damping resistor, the discharge capacitor, the spark gap and the current probe.

NOTE It is important to ensure that the discharge loop is as small as possible for achieving the transient pulse duration objective defined in 5.5.12.4.5.5.12.4b.4.

e. For calibration the test equipment is configured as shown Figure 5-30, and meeting following provisions:

1. the discharge circuit is not coupled to the EUT,
2. choke resistors are near the capacitor,
3. the current probe monitoring the primary current from the ESD source is near the damping resistor, at the capacitor side,
4. the high voltage probe is measuring the voltage across the capacitor, grounded at the damping resistor side.

NOTE The high-voltage probe is not meant to measure the voltage during the discharge but the voltage reached before discharge

f. Test the EUT by configuring the test equipment as specified in Figure 5-31 and meeting the following provisions:

1. the high voltage probe used for calibration is removed,
2. the EUT is mounted on a conductive ground plane using the space vehicle mount and attach points, and operated using the actual electrical harness, or an EMC test harness of identical construction to the actual harness.

NOTE It is preferable to use the actual electrical harness.

3. the discharge circuit is supported 5 cm above the ground plane by a non-conductive standoff with high-voltage insulation capability,
4. from calibration, the discharge circuit is kept unchanged in size and shape, and tightly electromagnetically coupled 20 cm along an EUT bundle, held by dielectric bonds

NOTE a maximum separation distance of 1 cm between the injection wire and the outer circumference of the bundle under test is a condition for achieving a tight electromagnetic coupling

5. a current probe is monitoring the primary current from the ESD source near the damping resistor,
6. a current probe is monitoring the current in the EUT harness, 5 cm from the EUT connector.

5.5.12.4 Procedure

The test procedures shall be as follows:

a. Turn on the measurement equipment and wait until it is stabilized

b. Perform a calibration using the calibration setup:

1. Select the spark gap device or adjust the spark length at the voltage breakdown to be used for the test
2. Turn on the high voltage generator

3. Using the high voltage probe, check the breakdown voltage value is stable and within ± 30% from the value to be used for the test.
4. Monitor the transient current pulse

NOTE A goal is 30A, 30ns duration at mid-height, rise time as short as possible. Means for minimizing the rise time are adjusting the damping resistor, reducing the size loop, checking that both choke resistors are as close as possible to the capacitor, and technology of the spark gap (nature of gas and shape of electrodes)

5. Record the last current and voltage couple, displayed with a common time reference
6. Repeat 5.5.12.4.b.4 and 5.5.12.4.b.5 with opposite polarity

c. Test the EUT as follows:

1. Fully power the unit during the complete ESD test.
2. Turn on the high voltage generator
3. Establish a pulse discharge at a pulse rate of 1 Hz, with a pulse direction of at least 15 positive and 15 negative.
4. Record the last primary and secondary current couple, displayed with a common time reference
5. Repeat 5.5.12.4.c.3 and 5.5.12.4.c.4 on each bundle interfacing with each electrical connector.

5.5.12.5 Data presentation

Superseding clause 5.3.10.4, data presentation shall be as follows:

a. Provide tables showing statements of compliance with the requirement and the induced current level for each interface connector

b. Provide oscilloscope records taken during calibration and EUT testing procedures

c. The requirement of 5.3.10.3 does not apply

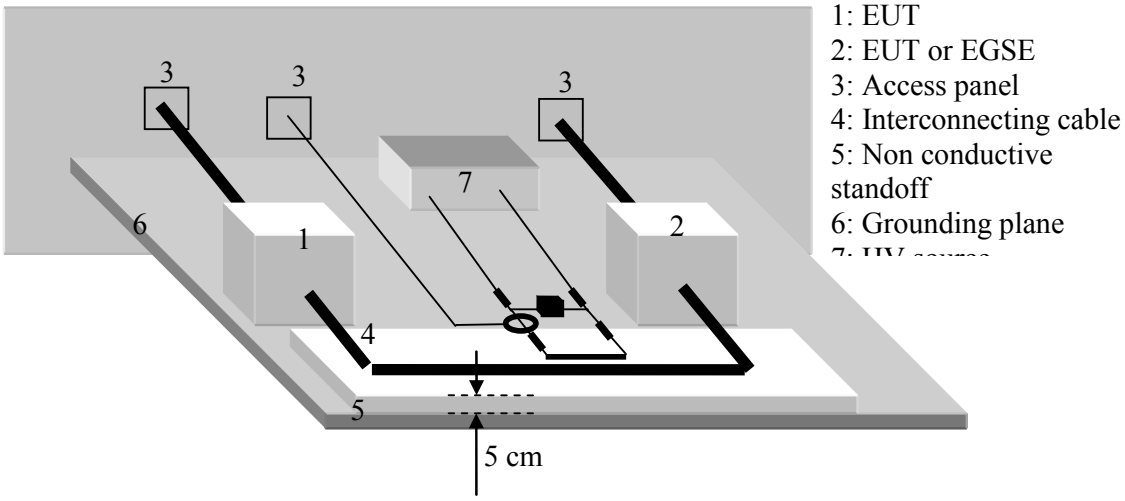

Figure 5-29: Spacecraft charging ESD susceptibility test

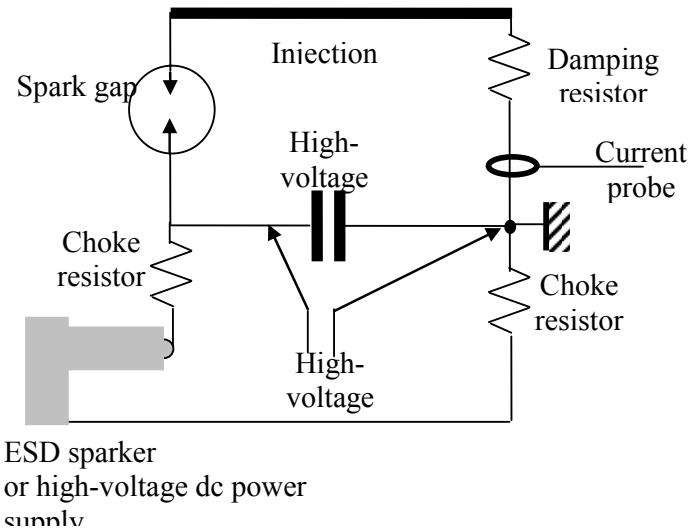

Figure 5-30: Susceptibility to ESD: calibration configuration

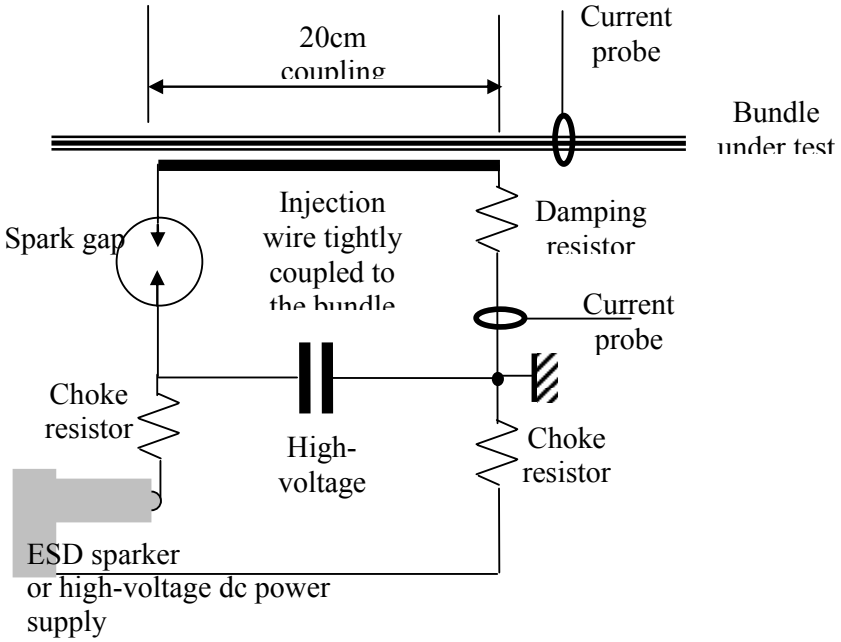

Figure 5-31: Susceptibility to ESD: test equipment configuration

Annex A (informative)
Subsystem and equipment limits

A.1 Overview

There is no single method for achieving EMC.

- Low susceptible equipment is for telecommunication spacecraft flying in a severe EMI environment due to on board large power and possible residual ESD
- Low emission equipment is for scientific spacecraft for preserving high sensitivity of detectors.

Therefore, it is not possible to define a same set of limits for all equipments of all spacecraft and launchers. The EMCCP is the vehicle for tailoring limits and test methods.

However, it is a legitimate demand of equipment manufacturers to ask for EMI limits outside the frame of a specific project. Conducted and radiated emission limits and susceptibility limits defined hereafter are recommended for space projects.

A.2 CE on power leads, differential mode, 30 Hz to 100 MHz

In differential mode, on each independent power bus, conducted emissions on power leads, induced by loads, can be limited in the frequency domain under following conditions:

- limits are in the range extending from 30 Hz to 100 MHz,
- a maximum I_{NB} in units of dB referenced to 1 µA is a function of frequency defined on Figure A- 1,
- in the low frequency range the limit ICE in units of dB referenced to 1 µA (dBµA) is function of the consumption I_{dc} (in amperes) of the equipment on the line, see Figure A- 2:

  $I_{dc}<1$ A $I_{CE} = 80$
  $1 \text{ A}<I_{dc}<100$ A $I = 80 + 20 \log_{10}(I_{dc})$
  $I_{dc}>100$ A $I = 120$

  The mode is called “differential” because measurement are done separately on hot and return wires, however it comprises common mode components.

  “Independent” means connected to separate power sources.

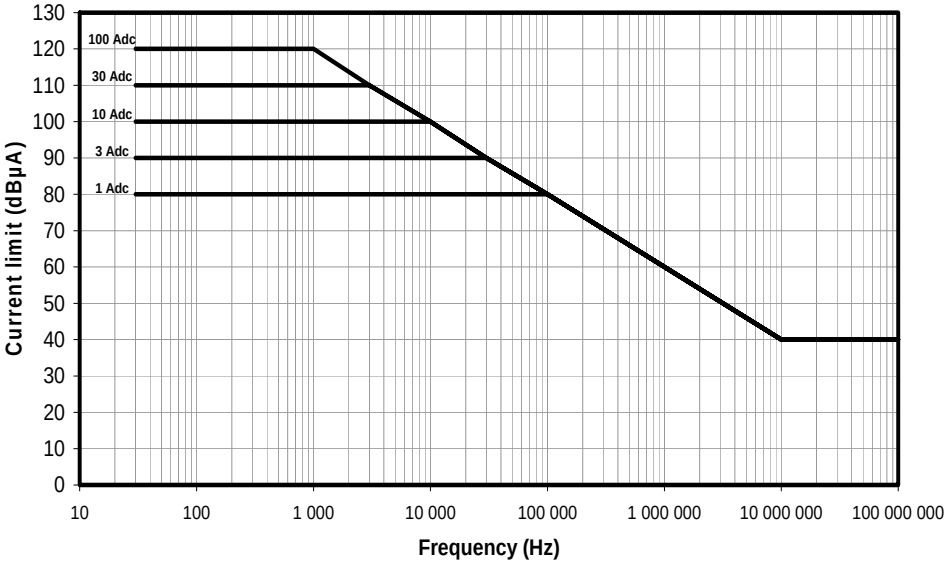

Figure A- 1: Power leads, conducted emission

A.3 CE on power leads, in-rush currents

The inrush current of an equipment on the power lines can be limited in the time domain with following characteristics in order to limit the voltage transients on the power bus:

- during any nominal change of configuration, the rate of change of current is limited to 5.10^4 A/s,
- at switching ON the rate of change of current is lower than 2.10^6 A/s, absolute value of rise and fall slopes.
  Specific requirements are usually defined for pulsed radars, plasma thrusters power units.

Limits can also be specified for the following characteristics in order to achieve compatibility with the upstream protections of the spacecraft power subsystem.

- inrush current duration (in ms)
- total charge (in mC)
- inrush current slope (in A/µs)

A.4 CE on power and signal leads, common mode, 100 kHz to 100 MHz

The conducted emissions on bundles in common mode can be limited with following characteristics:

- limits are in the range extending from 100 kHz to 100 MHz,
- I_{CE} in units of dB referenced to 1 µA (dBµA) is lower than the curve of Figure A- 3,
- the same limit is defined for all cables taken together or bundle per bundle.

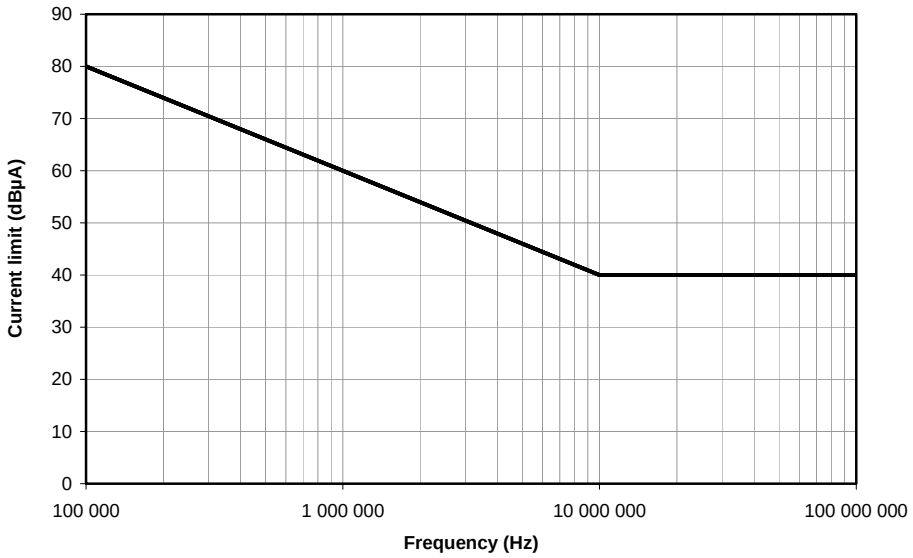

Figure A- 2: Common mode conducted emission

A.5 CE on antenna ports

Spurious conducted emissions on antenna ports can be limited to following values:

- receivers 34 dBµV,
- transmitters (stand-by mode): 34 dBµV,
- transmitters (transmit mode):
  - harmonics, except the second and third, and all spurious emissions: 80dB down the level at the fundamental,
  - the second and third harmonics 50 +10 log P (where P is the peak power output) or 80 dB whichever is less.
    Equipment with antennas permanently mounted are not in the scope of this clause.

A.6 DC magnetic field emission

A.6.1 General

The DC magnetic field emission generated by subsystems, equipment and elementary components is limited or characterized for following purposes:

- for establishing the magnetic momentum of the whole space vehicle,
- for establishing the composite DC magnetic field at critical locations.
  The components of the magnetic emission are DC current loops, solenoids, the permanent field of hard magnetic materials (magnets) and the induced magnetic moment by the Earth-field on soft magnetic materials, including hysteresis.

A.6.2 Characterization

Following parameters of magnetic properties can be determined or characterized:

- permanent induction parameters of operating EUT by determination of magnetic induction B in units of μT under magnetic zero-field condition,
- induced parameters of not operating EUT by determination of magnetic induction B in units of μT when immerged in a uniform controlled field of 30 μT (calibrated in absence of EUT) in each of 3 rectangular semi-axes, in both directions,
- Determination of the DC magnetic field emission is performed by either measurement or similarity.
- Determination by similarity is applied to equipment or subsystems coming from other programs, where re-use as it is or re-use with only little modification.
- Assessment of the dipole model by measurement of magnetic induction B at least at two different distances r and comparing respective products r^3(m) B(μT),

  NOTE Distances in the range 0.5 m to 1,5 m can be used.
- Magnitude of the magnetic dipole, (when the equipment is assimilated to a dipole) either:
  - by its magnetic moment or
  - by the magnetic induction at some distance of reference.
    When the unit is assimilated to a dipole, the inverse cube law dependence with distance applies, the following relation (worst case) is used for the equivalence between the magnetic moment and the induction at the distance d:
    B(T) = 2,10 – 7 M(Am2) / d(m3)
- characterization of the magnetic source when the dipole approximation is inadequate, either by:
  - a multiple moment model, or
  - a spherical harmonics model, or
  - the magnetic induction at the distance of measurement.
    The distance of reference is specified by the EMCAB in function of the size of the space vehicle or of the actual distance between magnetic sources and susceptible equipment.
    The magnetic induction is a rough indication that can be sufficient for some applications.
    The multiple-moment model or the spherical harmonics model is a precise determination sometimes needed for sensitive payloads.
    Specific characterization methods are implemented for the multiple-moment model or the spherical harmonics identification.

A.6.3 Limit

The DC magnetic emission of subsystems or equipments can be limited at a level of 0,2 μT at a distance of 1m from any face of the equipment.

This limit corresponds to dipole-like equipment with a magnetic moment of 1 Am^2.

The limitation is achieved through a combination of techniques: current loop area minimization and coaxial or twisted cables use, non-magnetic material use, magnetic shields use, compensation techniques with magnets.

A.7 RE, low-frequency magnetic field

- From a few hertz to 50 kHz, the magnetic-field radiated emissions can be measured.
- Measurement can be performed at several distances for characterizing the accuracy of a dipole model.
  If the EUT can be assimilated to a magnetic dipole, emission limits are expressed by its magnetic dipole momentum
- No limit is defined at equipment level.
  The measurement is only for characterization and useful to verify compliance at system level through analysis.
  Techniques for fulfilling EMC requirement at system level are an appropriate grounding network, magnetic shields, an optimized location of equipments on the space vehicle

A.8 RE, low-frequency electric field

- From a few hertz to 30 MHz frequency range the electric-field radiated emissions of units can be measured.
  The frequency limits are determined by the EMCAB from payload specifications.
- The electric field emission from the equipment is expressed in units of dB above 1 μV/m at a distance of 1 m.
- Measurements at several distances are performed for characterizing the decay law.
- No limit is defined at equipment level.
  The measurement is only for characterization and useful to verify compliance with system level requirements through analysis.
  Techniques for fulfilling EMC requirement at system level are reduction of common mode conducted emission from bundles, and electric shields or appropriate location of equipments on the space vehicle.

A.9 RE, electric field, 30 MHz to 18 GHz

In the 30 MHz to 18 GHz frequency range, electric-field radiated-emissions from equipment and subsystem including interconnecting cables can be limited under following conditions:

- the limit applies to:
  - non-RF equipment,
  - RF equipment connected to passive loads or EGSE, in nominal mode, at nominal power,
- the limit is defined by the curve on Figure A- 4,
- the limit is for both horizontally and vertically polarized fields,
- the limit comprises notching lines for launchers or spacecraft receiving bands not represented on Figure A- 4.
  Additional requirements can apply beyond 18 GHz if SHF or EHF payloads are present. These are beyond the scope of the present standard.
  For equipment having all internal rise times longer than 35 ns, the specified upper frequency limit can be reduced to 1 GHz
  For non-RF equipment if the emission is lower than 20 dB below the requirement between 500 MHz and 1 GHz the specified upper limit can be reduced to 1 GHz, with the exception of notches above 1 GHz, still to be tested

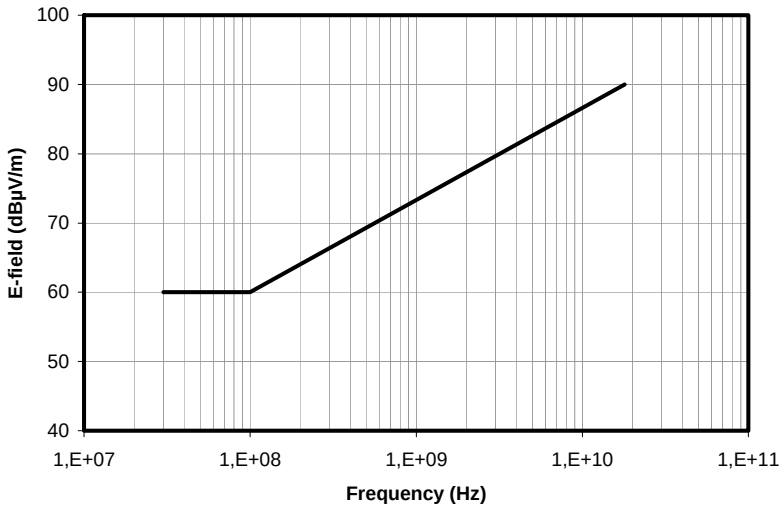

Figure A- 3: Radiated electric field limit

A.10 CS, power leads, differential mode, 30 Hz to 100 kHz.

- The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for the susceptibility test on the power leads specified in clause 5.5.7.
  - the injected voltage level is equal or larger than the level on Figure A- 5,
  - a limitation of the injected current before the specified voltage is reached is applied:
    - the limit of current is 1 A_{rms}
    - the voltage level when the current limit is reached is measured and reported.
- The current applied is reported.
- Independent power lines are tested separately.

  NOTE Independent means “connected to separate power sources”
- Except in the case of structure return, for each power line, hot and return wires are tested separately.

  NOTE In case of structure return, the test is only applied to hot wires
- The test signal covers the [30 Hz-100 kHz] frequency range.

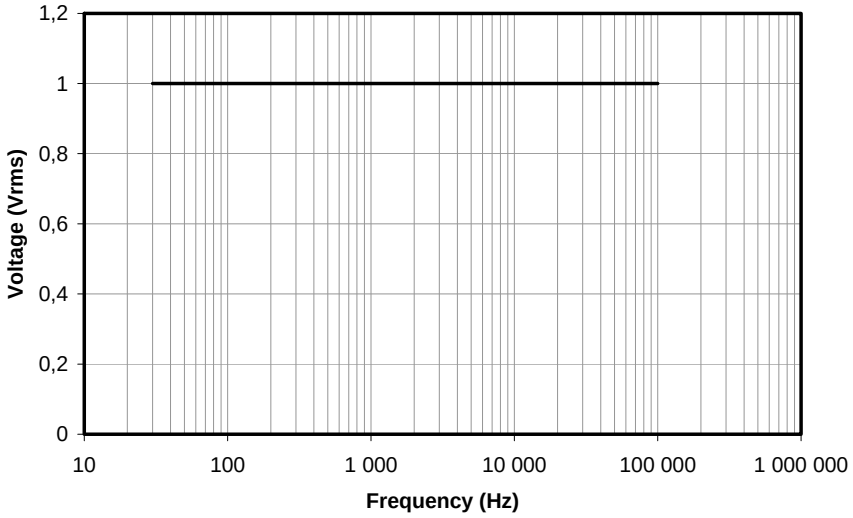

Figure A- 4: Conducted susceptibility limit, frequency domain

A.11 CS, power and signal leads, common mode, 50 kHz to 100 MHz

- The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for the susceptibility test on the power and signal leads specified in clause 5.5.8:
  - the common mode level of 3 volts peak to peak or larger is applied,
  - the limit of the current induced on the bundle is 3 A peak-to-peak
  - the test signal is pulse modulated,

    Square wave modulation is a particular case of pulse modulation
  - the duty cycle is depending on the carrier frequency, according to Table A- 1.
- The same level is applied to all cables together or to bundles taken separately.
- The common mode induced current on the bundle is reported.
- The test signal covers the [50 kHz-100 MHz] frequency range.

Table A- 1: Equipment: susceptibility to conducted interference, test signal

Frequency range	Pulse repetition frequency	Duty cycle
50 kHz-1 MHz	1kHz	50% (squarewave)
1 MHz-10 MHz	100 kHz	20%
10 MHz-100 MHz	100 kHz	5%

A.12 CS, power leads, short spike transients

- The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for the transient susceptibility test on the power lines specified in clause 5.5.9:
  - a series of positive spikes, then a series of opposite spikes superposed on the power voltage shall be applied,
  - at any time step, the voltage spike amplitude is:
    - +100% or -100% of the actual line voltage if the nominal bus voltage is lower than 100 V, Figure A- 6.
    - +50% or -100% of the actual line voltage if the nominal bus voltage is equal or larger than 100 V.
      Level 0 on Figure A- 6 represents the DC bus voltage.
      Only the positive spike is represented on Figure A- 6.
      When a negative spike is applied, the absolute instantaneous transient voltage goes down to 0, never negative
  - tests are performed with two spike durations, the first zero-crossing is at T=150 ns and at T=10 µs.
- Independent power lines are tested separately.
  Independent means "connected to separate power sources"

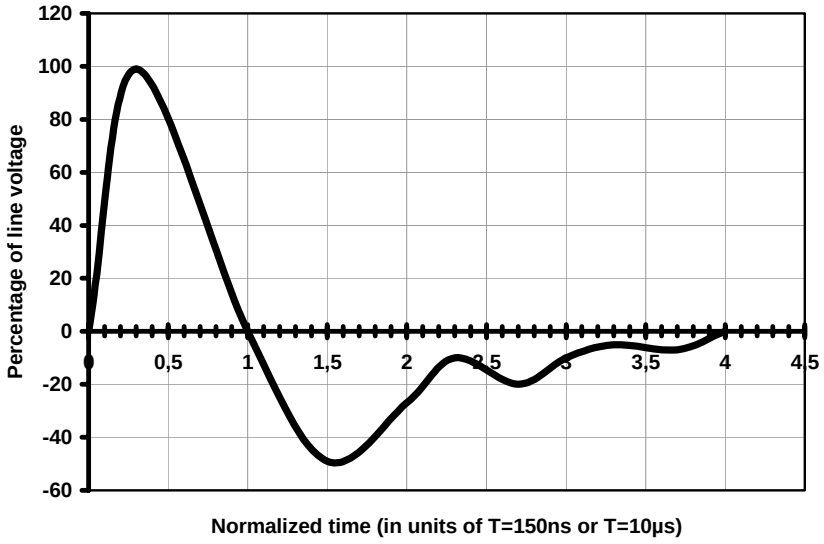

Figure A- 5: CS, voltage spike in percentage of test bus voltage

A.13 RS, magnetic field, 30 Hz to 100 kHz

- The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for the radiated susceptibility test, magnetic field, specified in clause 5.5.10:
  - the amplitude of the test signal is equal to or larger than the level on Figure A- 6,

- the source is located at 5 cm of any face of the EUT.

- The signal test covers the [30 Hz-100 kHz] frequency range.

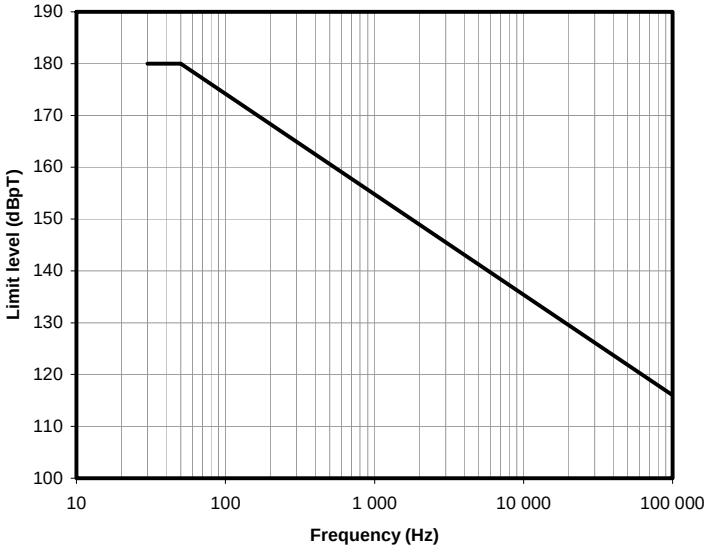

Figure A- 6: Radiated susceptibility limit

A.14 RS, electric field, 30 MHz to 18 GHz

- The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for radiated susceptibility test, electric field, specified in clause 5.5.11:
  - the amplitude of the test signal is:
    - — equipment in the vicinity of beams, outside of the main frame considered as a Faraday cage, : 10 V/m,

      An electric field of more than 10 V/m is applied if RF analysis demonstrates that the expected electric field seen in flight by the equipment is larger.
    - — equipment far from main lobes and secondary lobes, outside of the main frame: 1 V/m,
    - — equipment inside the main frame: 1 V/m,
      At RF transmit frequencies, the RS level should be tailored up; at RF receive frequencies, the RS level should be tailored down for receivers.
  - an AM or PAM test signal is used,
  - both horizontally and vertically polarized fields are used,
  - circular-polarized fields are not used.
- The signal test covers the [30 MHz-18 GHz] frequency range
  Additional requirements can apply beyond 18 GHz if SHF or EHF payloads are present. These are beyond the scope of the present standard.

A.15 Susceptibility to electrostatic discharge

- The following dispositions, known to be achievable and already specified in other standards or project specifications, are proposed for the ESD test specified in clause 5.5.12.
- The test is performed on following equipment, including or not digital circuits:
  - units comprising high-voltage power sources,
  - units man-handled during normal operation,
    This condition applies to manned-flight,
    For man-handled equipment, an ESD test by the contact discharge method as defined in IEC-61000-4-2, is more appropriated,
  - units outside the main frame of the space vehicle designed as a Faraday cage,
  - units connected to sensors, actuators, or other units located outside the main frame designed as a Faraday cage with the exception of the solar array power bus.
- Specific tests defined in ECSS-E33-11 are applied to EED's.
- Test of models expected to be or to become flight models is not performed.

  ESD testing can cause latent failures of test article.

Bibliography

[1] MIL-STD-461E, Requirements for the control of electromagnetic interference, characteristics of subsystems and equipment, 20 August 1999; Department of Defence, USA.